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[STANDARDISATION OF INFRASTRUCTURE THAT SUPPORTS INNOVATION: THE CASE OF THE DUTCH EV CHARGING INFRASTRUCTURE]

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Abstract

The purpose of this research is to describe the standardisation for infrastructure that supports innovation. The case for this qualitative research is the charging infrastructure for electric vehicles in the Netherlands. Both the standardisation process and the types of standards that were developed were investigated. This is reflected in the following research questions:

RQ1: What aspects influenced the standardisation process of the Dutch EV charging infrastructure and what implications can be identified for innovation?

RQ2: What types of standards were developed for the Dutch EV charging infrastructure and what implications can be identified for innovation?

The main scope of this case study is infrastructure for AC normal charging on (semi-)public ground. In total 17 stakeholders that were involved in building this infrastructure were questioned, using semi-structured interviews. The results include a chronological description of events and the view of the different stakeholders on standardisation and innovation. The analysis of these results is based on a theoretical framework that describes the process of standardisation and the types and functions of standards.

Important aspects of the standardisation process were the long-term view of grid operators and governmental support to engage stakeholders. The standardisation was executed in a formal and informal process. The formal process included the standard-setting body NEN. The informal process involved meetings of stakeholders in order to provide compatibility in the infrastructure and to solve practical problems. Supportive for innovation were the focus on avoidance of technological lock-ins and the focus on enabling competition. Standards were developed to ensure compatibility between different charging stations and EV service providers. This compatibility was seen as necessary to execute a market model which involves a multitude of companies, competing with each other.

As a formal standard, the use of the Dutch Technical Agreement (NTA) was a smart move to combine the flexibility and pace of an informal agreement with the stability of a norm. Flexibility in the standards, by describing only performances, was seen as beneficial for innovation in charging infrastructure, but was limited to communication compatibility standards. Stability of the Dutch EV charging infrastructure was created by choosing a fixed design for the socket of charging stations and by creating a roaming model for EV service providers by convention.

Preface

This research is inspired by Movares: an engineering consultancy firm in Utrecht, the Netherlands. The company has over 1200 employees and is active in the areas of mobility, infrastructure and transportation systems. One of their departments (Movares Energy) has taken the concept of electric mobility as a main topic for their business. The initiator of this program, Rik Luiten, acquired the chairmanship of NEN NEC 69, the Dutch technical committee for standardisation of electric vehicles. I obtained an internship at this department and Rik Luiten is my mentor inside Movares.

I want to thank Rik for his pragmatic advice for this research and his help to find interview participants. Next to him, I want to thank Jacco Farla for his supervision from Utrecht University. I valued his tips and comments enormously.

Finally, I want to express my gratitude to all participants that made this research possible by spending their time to answer my interview questions.

Christian Michel

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Content

1. Introduction

The transition from internal combustion engine (ICE) automobiles to electric vehicles[1] (EV) may be one of the greatest challenges concerning mobility that governments and a broad spectrum of organisations face in the upcoming decades. EVs promise several benefits for society, like less-polluted air (especially in urban areas) and more efficient energy conversion for transportation which results in a reduction of oil-dependency (Van Vliet et al., 2011). Particularly, this last aspect of EVs played a role in the 1970s during the oil crisis in the decision of governments to support the development of EV. Nowadays global warming concerns and the possibility to drive solely on sustainable-produced electricity is an additional motivation for nations to pursue the transition to a system that supports EVs (Richter et al., 2008).

Despite those motivations, the market for EVs is still insignificant in comparison to the market for ICEs, which could indicate problems in the transition. One aspect of these problems is the consumer choice for the vehicle, which involves 'range anxiety' (the fear to end up with an empty battery on the road) and willingness-to-pay (Hidrue et al., 2011). Another aspect is the infrastructure that is needed for a successful adoption of the EV. Such an infrastructure includes public and private charging stations, electricity production and power grid operations.

Markets that require an infrastructure-related system are known for their monopolistic or oligopolistic character (e.g. banking, telecommunication and railway). According to Arrow (1962) such market structures hamper innovation, which increases costs for society. In order to solve this problem, standardisation might provide an important mechanism (Egyedi and Spirco, 2011). The choice for a standard can go without fierce competition, when industry alliances decide on a standard. However, it is also possible that a struggle takes place for many years, resulting in clear winners and losers (e.g. HD-DVD versus Blu-Ray).

A major aspect of standardisation is timing: Too early standardisation can lead to the wide adoption of an inferior technological solution. However, when no standards are in place, inefficiencies might occur as well. Egyedi (2010) describes the case of mobile phone chargers, where recognition of market failure led to intervention by the European Union. *"The benefits of a common standard were clear: it would convenience consumers, benefit the environment and help industry to meet the requirements of the European Directive for Electronic Waste (WEEE)"* (Egyedi, 2010:12).

For the case of the charging infrastructure, standardisation has especially implications in terms of compatibility. For example, to provide convenience for EV drivers, charging stations from different providers should work and communicate in the same way with the driver, the vehicle and the electrical grid.

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[1] In this paper, the definition for electric vehicle is according to the Dutch engineering consultancy Movares: A vehicle that can be charged on the power grid. This involves vehicles that drive solely on electricity (Battery-Electric Vehicles), but also Plug-In Hybrids (Luiten, 2011). This is in accordance with Van den Bossche (2010:542), who claims that these vehicles "should be considered equally for their infrastructure needs".

2. Problem Description and Research Question

Initially, private parties in the Netherlands took the lead to come up with market settings for EV. However, the Dutch government recognised the need to play a key role in the development of the EV as well. Now, the Netherlands wishes to be a front runner in Europe in the facilitation of a national charging infrastructure (Rijksoverheid, 2011). Yet, this should not be realised at the expense of a healthy market competition. A market competition can be seen as healthy when it stimulates innovation, through which companies pursue to offer improved services and products to society at a competitive price (OECD, 2007). The Dutch Ministry of Economic Affairs, Agriculture and Innovation (ELI) asked different consultancies to provide a model that provides such circumstances for the market of charging electric vehicles. This led to studies by Accenture (2010) and Boekema et al. (2010). In these studies, a distinction is made between the 'network model' and the 'platform model' for charging EVs. The platform model means that the operation of a charging station includes offering of payment options for customers and these payments go directly to the operator. In the network model, the ownership and operation of charging stations is separated from the actor who provides contract services for charging EVs. According to Boekema et al. (2010:2): *"In the long term, a network model will lead to maximum dynamics, freedom of choice and innovation"*. Figure 1 presents a possible network model that includes different market roles.

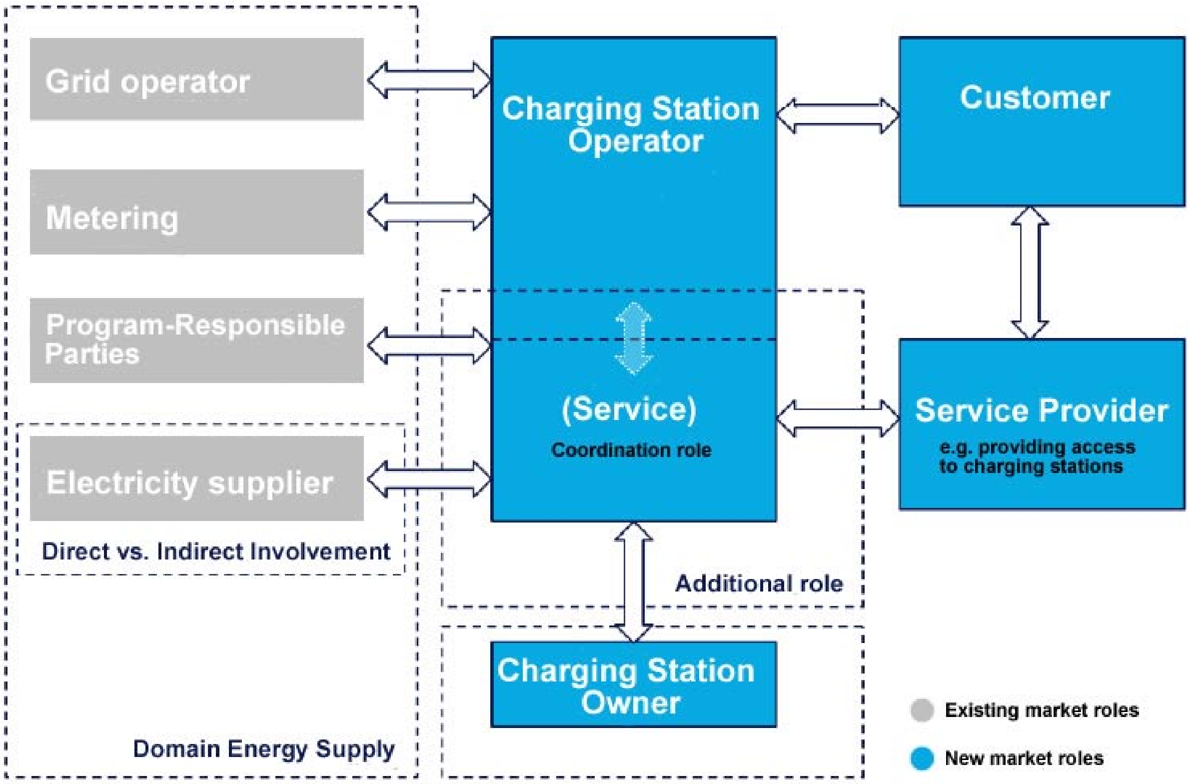

Figure 1. Relationships network model example (Adapted from Boekema et al., 2010; Accenture, 2010)

It is important to notice that these different roles do not have to be accomplished by different actors. Thus, roles can coincide. In such a market environment, communication between the actors is vital. Figure 2 provides an overview of the communication issues involved.

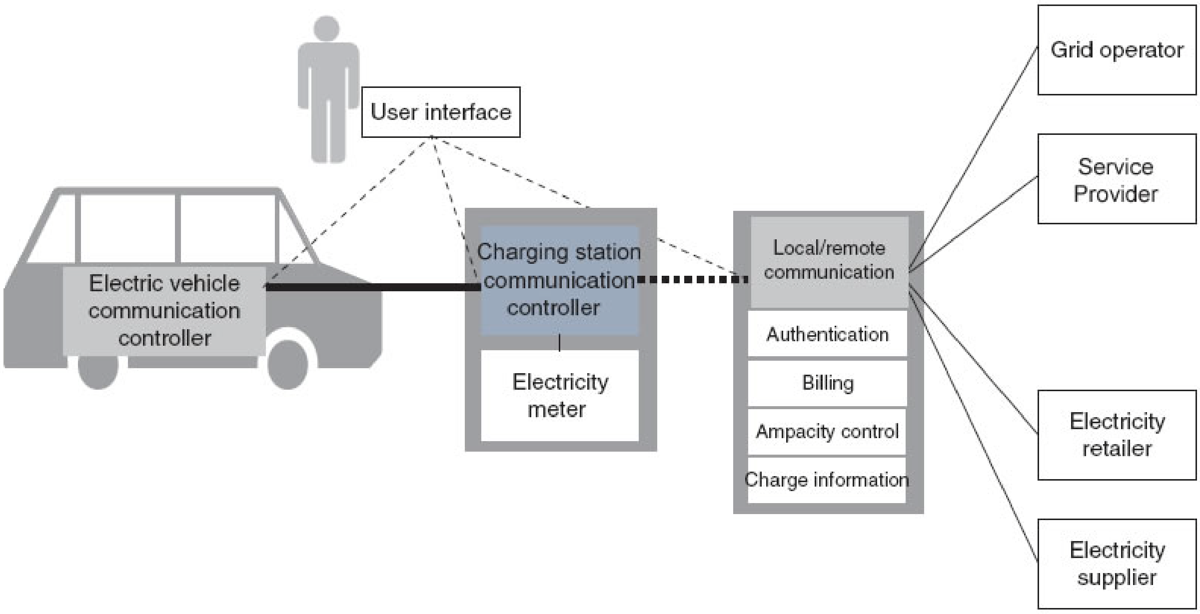

Figure 2. Communication involved in the charging process (adapted from Van den Bossche, 2010)

The EV user has to interact with the vehicle, the charging station and the provider in order to be granted access to the station. The charging station has to communicate with the EV to guarantee safe supply of electricity and it measures the amount of electricity taken. Next to this, the charging station can handle issues like authentication, billing, control of the correct amount of current the device can carry (ampacity) or other information about the charging process (Van den Bossche, 2010). It can do this either locally or remotely. Such data or actions can be important for different stakeholders, like grid operators, service providers, electricity retailers and electricity suppliers.

In order to communicate effectively, standards are key. With standards, each transaction can occur in the same way which provides the efficiency that is needed to let such a system work.

The importance of standards is also emphasized by Geoffrey A. Moore (2002). He describes the technology adoption life cycle and the 'chasm' between early adopters and early majority (see fig. 3).

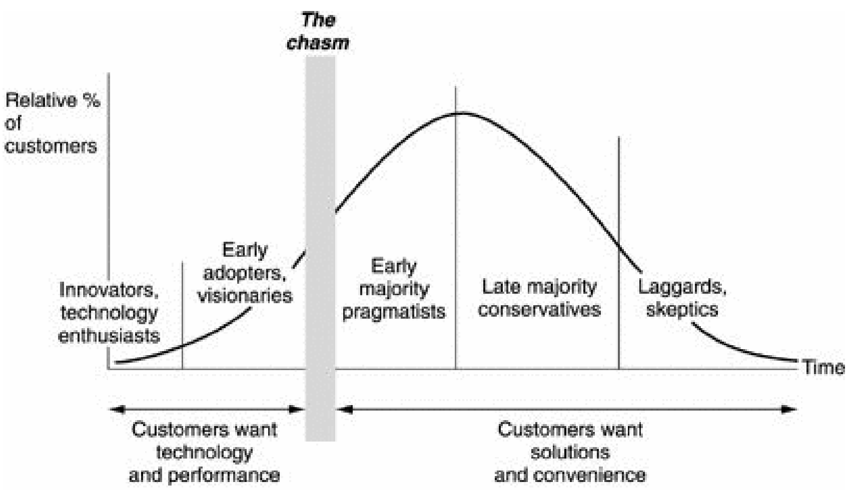

Figure 3. The technology adoption life cycle and the chasm (figure from Norman, 1999)

The first customers of electric vehicles are attracted by the 'new' way of mobility that is presented by the EV technology. Shortcomings like low range and long charging times are seen as challenges, not problems. In contrast to this, the early majority wants a solution presented to them for these issues and wants convenience. An important example is the need of an infrastructure in order to overcome range anxiety. Standards for this bring convenience to customers and convince them about this solution. Early adopters know they are too early with a technology to expect well-established standards, components from third parties, support groups or fixed procedures. However, *"pragmatists expect all these things"* (Moore, 2002:58) and therefore, to let electric vehicles cross the chasm, standardisation of the charging infrastructure is essential.

Standardisation is all about creating stability. Innovation is all about change. Innovation involves creative destruction according to Schumpeter (1994). That is why the main perception exists that those two things cannot work together (Blind, 2009). However, research shows that it is not a contrast per se (DTI, 2005). The following quote presents a nice metaphor about the relationship between standardisation and innovation:

> *"Compare the role of standards towards innovation with the role of pruning and training fruit trees to promote fruitfulness. Yes, pruning and training constrains and limits the growth of the tree; but done right, it can help to promote the growth of healthy fruit." (Swann, 2010:9)*

The part '*but done right*' is important here. This implicates that the right standardisation is necessary in order to reap the rewards that come from innovation. This is not easy: the process of standard-setting involves a lot of complexity. International and local developments occur simultaneously and actors with different power levels have different stakes at play. Several types of standards and technological solutions exist, on which stakeholders have to find an agreement. These are all important aspects that influence standardisation.

This thesis will contribute to this discussion by answering the following two research questions:

RQ1: What aspects influenced the standardisation process of the Dutch EV charging infrastructure and what implications can be identified for innovation?

This describes the aspects that played a role in the standardisation process and its impact on innovation. Theory about policy for standardisation is used as a guidance in analysing the results from the case study.

RQ2: What types of standards were developed for the Dutch EV charging infrastructure and what implications can be identified for innovation?

Next to the process, the standards themselves have an impact on infrastructure. A description is given about the standards that are used for the case of charging infrastructure in the Netherlands. As the theoretical section will show, some type of standards are more appropriate in supporting innovation than others. Literature offers a broad classification for these types and functions of standards. The guidance of the literature helped identifying the implications for innovation in the Dutch EV case.

Research about the influence of standardisation of charging infrastructure for innovation can be considered as social relevant. Members of standard-setting organisations pronounced it as useful to learn about the consequences of their decisions for innovation (Luiten, 2011). In addition, the case study provided in this thesis is scientific relevant through its unique character: the Netherlands is the first country that built a charging infrastructure according to a market model, which is meant to support innovation in the long run (Boekema et al., 2010). The conclusion in this thesis entails implications for standardisation literature and therefore enhances the theoretical knowledge about this subject. Next to this, a rich description of the standardisation of the Dutch infrastructure is useful to be studied by scholars in other countries. Researchers might look for examples of standardisation of charging infrastructures, which could be adopted or rejected for their nation.

Outside the scope of this paper are other factors such as government regulations or customer behaviour, which obviously play a huge role as well in the success of electric mobility. However, these factors deserve their own investigation in order to provide real, in-depth information about these issues.

3. Theory

The goal of this theory section is to provide argumentation against the view that standardisation and innovation is a contrast and to enlighten the role of standards further. The following section will describe policy for the process of standardisation. After that, I explain the different types and functions of standards and the relation with innovation and infrastructure.

3.1 The Process of Standardisation

Literature provides policy recommendations for the process of standardisation. This description is used as a guidance in understanding the Dutch process concerning the standardisation of charging infrastructure.

It is important to understand how complex the process of standardisation is in the case of EV charging infrastructure. Electric vehicles are linked to an entire chain of different industries and social aspects: energy, mobility, infrastructure and information technology (Kreukniet, 2012). This is hardly the case of one market, but more of a system that includes multiple markets. Edquist (2001) mentions that innovations occur in firms and that this does not happen in isolation. He uses a systemic approach to explain that firms innovate in interaction with standard-setting agencies and that this interaction is shaped by institutional rules. Smith (2000) emphasises that a key aspect of the systemic approach is the influence of technical standards. Technical standards are in turn influenced by the regulatory system of a nation. Therefore, the process of standardisation is not only an issue for company policy, but also for government policy. To conclude, standardisation is an essential factor in policies about competitiveness, innovation and science & technology (DIUS, 2009).

Scholars investigated aspects that determine the chance of participation of companies in the standardisation process. Blind (2006) concludes that company size is a significant aspect and the larger the size, the higher the probability of involvement in standardisation. He further states that both R&D intensity and export activities show an inverse U relationship with the probability of participating in standardisation. This means that the increase of these aspects increase the chance of participation, up to a point that further increase decreases the probability of involvement again. Explanation comes from the fact that very R&D oriented firms and companies that export a lot expect disadvantages through active membership in standardisation committees. A disadvantage felt by these companies is negative knowledge spill-over (Blind, 2006).

To limit this danger, Iversen et al. (2006) recommend to combine the purposes of formal standard-setting bodies with intellectual property rights. They claim that a balance should be achieved between the collective benefits of a common standard and individual profits from the firm's R&D results. This asks an interaction between research, innovation and the standardisation process (Iversen et al., 2006). The interaction with researchers is also emphasised by Blind and Gauch (2009:340): *"standardisation (…) requires the tacit knowledge of researchers to be integrated in the standardisation process to produce results that reflect both the needs and realities of researchers and developers"*.

Swann (2010) includes these factors and combines them with other recommendations, found in an extended literature study. In the 'ideal model' for policy, he justifies the following policy options for standardisation:

(a) Engagement of Stakeholders

In standardisation, history especially shows the involvement from large organisations. These big businesses can afford the time and money on standard-setting processes. However, the effects of standards influence more stakeholders, which gives policy makers a reason to engage a broader spectrum of stakeholders in the standardisation process. Acceptance of standards is just as important as developing them, that is why many stakeholders should be connected to the standard-setting process.

(b) Updating the Stock of Standards

Standards, just like products, have a life cycle and eventually become outdated and unnecessary. To make the standard-setting process more efficient, it is important that a catalogue of standards exist that is up-to-date and not blocked by standards that in practice have no value any more. The usefulness of a stock of standards increases with the number of standards included, but has a point in which too many standards decrease this usefulness (DTI, 2005). The same happens with the average age of standards: the information included becomes more valuable over time, until at a certain moment a standard becomes too old and its value decreases (DTI, 2005).

(c) 'Big Issues'

This is the recommendation to involve systems thinking in standardisation. It seems beneficial to have the greater picture in mind and being able to consider (negative) side-effects of activities. Especially when these activities promise short-term gains. An extended argumentation in favour of systems thinking is presented by Nelson and Stolterman (2003). They claim that emergent qualities like patterns (e.g. side-effects) disappear when only dissembled parts are observed and not the full system.

(d) Integration with Research and Innovation

To involve the (academic) research community in standardisation is another policy option that is regarded as valuable. This is related to (c), because researchers and innovators are trained to look at the greater picture. It seems advantageous for the innovation system to strengthen the links between research, innovation and standardisation. For the results of the standardisation process it is valuable to involve the tacit knowledge of researchers (Blind and Gauch, 2009). For R&D in turn, it makes sense to use the benefits of a common standard (Iversen et al., 2006).

(e) Access to Standards and Pricing

Often, standards bodies require payments for the access to standards, in order to pay their activities. The prices are usual modest, but its existence can present a hurdle to e.g. smaller organisations. The recommendation is to provide (price-) differentiated products that serve different types of organisations, instead of an One Size Fits All approach. An example is the German DIN, whereby SMEs can buy a discount package of a certain number of standards.

(f) Coordination of Different Government Activities
Conflicting standards can arise from the absence of coordination between different agencies and their standardisation activities. Especially this takes place in systems whereby activities are separated by certain social areas or industries, but the effects of their standards intertwine. In such systems, coordination is recommended. Again, this is related to (c) whereby the need of systems thinking presents itself.

In the analysis part of this thesis, a description is given about the Dutch process in setting standards which will use the above sensitising concepts as backbone. According to Bryman (2012), sensitising concepts are concepts with the goal to give a sense of reference and guidance for the researcher. To use concepts in such a 'sensitising' way is highly recommended for qualitative research (Bryman, 2012).

3.2 The Types and Functions of Standards

In academic research, different taxonomies for standards are postulated. The criteria for typologies I chose for this research are the economic function of a standard, the creation-process of a standard and the formulation of a standard. I present an overview of the most common typologies that will be used in this paper below.

Tassey (2000) recognises four functions that standards fulfil in a technology-based economy, which are summed up in table 1.

Table 1. The economic functions of standards

Function	Explanation
Quality/Reliability	Specifies acceptable performance
Information	Provides measurement and test methods
Compatibility[2]	Specifies properties to work together with other products
Variety Reduction	Limits the available options to choose from

In addition, the compatibility function can be divided into three types of compatibility (Farrel and Saloner, 1987). Raina König (2008:8) summarises these types as follows:

> *"a) Physical compatibility: This kind of compatibility is given in the case that different physical objects or components are designed in order to match each other. Examples are peripheral equipment for computers or the plug and the socket.*

[2] Tassey (2000) uses next to 'compatibility' the term 'interoperability'. While subsystems can 'interoperate' with each other without an actual pre-made agreement, compatibility is often used to describe when components work together by agreement. However, often the terms are used interchangeably. For this paper, I use the term 'compatibility', because standardisation is all about (more or less formal) agreements between stakeholders.

b) Communication compatibility: Physical objects or components are designed in order to communicate with each other. Examples are bus systems in automotive, electronics or computer language.

c) Compatibility by convention: Under this class of compatibility advantages of coordination exist that are not embedded in the product itself. Examples are banking cards or currency."

A different distinction between standards is based on the process of standard-setting, especially on the entities which enforce the standard (David and Greenstein, 1990; Hanseth, 1996). These types of standards are listed in table 2.

Table 2. The loci of standards

Type	Locus
Formal standards	Standardisation committees (e.g. IEC, NEN)
De facto standards (informal)	Private companies (e.g. windows, QWERTY)
De jure standards	Government (e.g. environment protection, driving speed limits)

When an industry agrees on a standard by itself, this is either through an association that develops a *formal* standard, or a *de facto* standard enforced by an influential company. A trajectory in which companies agree among themselves to use a certain method and/or technology, but without including a formal standard-setting body, can be seen as the *informal* way to create a de facto standard. Both, these formal and informal standards are developed inside an industry. However, the third standard, de jure, is imposed by governments from the outside and when directed at companies, is a form of regulation. In practice, the line of demarcation is less clear. Regulation policies can be captured by actors with special interest (Gómez-Ibáñez, 2003:55) and formal standards can be enforced by law to make them *de jure*. For the purpose of clarification, I use this typology to explain where a standard was created initially, not where the motives behind it come from.

Standards can be formulated in various ways. One main distinction that is adopted by standardisation scholars is the difference between an elaboration that is based on the design or the performance of a good (Egyedi and Spirco, 2011; Tassey, 2000; Blind, 2009). This is shown in table 3.

Table 3. The formulations of standards

Type	Elaboration
Design-based standards	Fixed design and material used
Performance-based standards	Fixed achievements

In the description of standards that are design-based, the exact layout and technology that has to be used is explained. Manufacturers that want to comply to this standard have to adopt the prescriptions by the letter. This in opposite to standards that use a performance description. These standards are written in a way that only prescribe the aim of the standard, for example a required set of actions or output format. How to achieve this is not mentioned: no preference for any technology how to accomplish the aim is given.

3.2.1 Standardisation and Innovation

In chapter 2, standardisation is compared with pruning fruit trees in order to grow healthy fruit. Standards can constrain and limit technological development, but if correct developed, they can promote innovativeness (Swann, 2010). Academic research found several recommendations for that challenge.

One is the development of *compatibility standards*. Egyedi and Spirco (2011) use three case studies to illustrate their point of compatibility standards as motor for innovation. By providing a gateway solution between subsystems, it enables individual innovations in those subsystems, without compromising the whole system. When such a solution is fixed in a certain product, the gateway is often called an '*interface format*' (Van de Kaa et al., 2011). An interface is the point between two subsystems and by agreeing on one format, the two subsystems can be developed independently of one another. Standards for information and communication technologies play an essential role in providing compatibility and support innovation through the increase of network effects (Swann, 2010).

A second recommendation is *the use of performance standards*. Aaron Gellman (1986) explains in his study about innovation in the railroad industry that encouragement of performance specifications above design specifications made sense, because suppliers could compete on these specifications with their own designs. That in contrast to design specifications, whereby the room for competition is trifled.

Moreover, *the use of formal standards* is an identified advice. Raina König (2008) takes the automotive industry as example par excellence to show the increase in importance of formal standard setting for innovation. Due to the accelerating technology life cycle of products, the increasing systemic nature of technology, its growing complexity and rising demand for reliability and quality, firms that try to enforce a standard on their own are in a disadvantageous position.

Those recommendations are fairly general, but show that there indeed *are* conditions in which one type of standard makes more sense than another. Regarding the network character of EV charging, the following step is to narrow the theory down towards infrastructure.

3.2.2 Standardisation of Infrastructure and Innovation

In the case of infrastructure, the problem with innovation is often the initial investment that has to be made upfront. Subsequently, this often results in natural monopolies (Gómez-Ibáñez, 2003:9). Such natural monopolies distinguish themselves from other kinds of monopolies by the fact that it is the most efficient way to have one company offering the service. The operation of EV charging stations represents a natural monopoly, because there is only one operator per station (Boekema et al., 2010:12). Comparable is the role of regional grid operators which presents a naturally monopoly as well, since they are the only suppliers of the physical network to those stations (Boekema et al., 2010:17). National governments often use regulation to avoid abuse of this monopoly position (Gómez-Ibáñez, 2003). An important aspect of a monopoly position is that once it is established, the firm controlling it is not expected to innovate to a large extent by themselves. It would only compete with itself and any radical new innovation would replace its own initial product (Arrow, 1962). A product on which customers are dependent anyway. However, that does not mean that innovation does not exist in such an industry. Service providers can be seen as supplier-dominated firms (Pavitt, 1984; Markard, 2011:114), thus the process of technology research is placed within their suppliers. Next to this, the size of companies plays a role. While large firms often have their own R&D lab, small and medium enterprises (SMEs) have suppliers as their main source of technological innovation (Tidd et al., 2005:162).

Yet, suppliers might not be the only drivers of innovation. As division of market roles continues (see fig. 1, p. 2), companies can specialise on the service part of the charging infrastructure. Such businesses may focus on their own service innovations instead of product innovations by suppliers.

Apart from the source of new technology, the possibility of implementing it is another major point for infrastructures. As stated in the section before, compatibility standards make it possible to realise pinpointed innovation in infrastructures, without compromising the entire system. Take the electric vehicle as example. By standardising the plug and socket of the car, car manufacturers can use all kind of battery technologies, without suppliers of charging stations having to adapt their stations and vice versa, as long as the plug and socket stay the same. However, for such interfaces, a physical compatibility standard is necessary, which involves a design-based standard. Thus, while performance-based standards are generally preferred, some conditions require design-based standards in order to promote compatibility (and through this innovation).

4. Methodology

This case study used two approaches to answer the research questions. The first was to gather information from written sources, like reports, web logs and discussions on social media. The use of social media might need some extra explanation, because of its new nature as a source for academic research. It was found, while preparing this research, that EV stakeholders are involved in several social networks that engage in online activities like sharing information through the microblogging service Twitter[3] and discussing topics on the social network website LinkedIn[4]. Especially in the Netherlands the use of those two media is widely spread among professionals (comScore, 2011). To neglect such a kind of activity and its value for this research would have been a missed opportunity. Table 4 provides the different sources that were consulted.

Table 4. Sources of online activities between stakeholders

Source	Online Social Network	Access (URL)
Microblogging between stakeholders	Twitter (list)	https://twitter.com/#!/emchris/electric-vehicle
Discussion group sustainable mobility	LinkedIn	http://www.linkedin.com/groups?gid=1954731&trk=myg_ugrp_ovr
Discussion group electric mobility	LinkedIn	http://www.linkedin.com/groups?gid=1455967&trk=myg_ugrp_ovr
Discussion group charging stations electric mobility	LinkedIn	http://www.linkedin.com/groups/Oplaadpunten-Elektrisch-Vervoer-4199055?trk=myg_ugrp_ovr
Discussion group platform electric mobility	LinkedIn	http://www.linkedin.com/groups?gid=2546090&trk=myg_ugrp_ovr

Information from these sources was used to learn about actions from stakeholders in the past. Such knowledge was essential in the preparation and execution of interviews (see the second method below). In addition to this, the weblogs served as a tool to find other sources about developments in the past. Posts from stakeholders often included web links to newspaper articles, which were used as references in the result section.

The second method was conducting semi-structured interviews with stakeholders. The advantage of this method was that it offered the opportunity to provide unforeseen information. While surveys or strictly structured interviews are very useful for testing assumptions, their limitation is that they operate within the problem conception of the researcher. A more open interview method offers the chance to widen this conception. A clear disadvantage of an interview technique that is too open, is the loss of focus. Valuable time might be wasted by conducting interviews that provide no or little useful data. The choice of semi-structuring the interviews is in the middle of those aspects (Baarda et al., 2010:230).

[3] Access: http://www.twitter.com
[4] Access: http://www.linkedin.com

The two methods were supplementary to each other. Data obtained during the desk research proved to be useful in conducting the interviews (asking the right questions, knowing the jargon), but in addition, the information that came from interviews turned out to be valuable in the search for written sources (access to reports and online social networks).

Another advantage of using these two methods was that both provided different degrees in neutrality and depth of the information. During the desk research, the investigator is an external observer which means that the information provided is less affected by any presence of the researcher. In contrast to interviews, whereby there is always the risk of influencing answers unconsciously (which of course was minimised). However, interviews provide more in-depth information than solely reading reports.

To provide greater reliability of the data collection, triangulation was essential. Data-triangulation is the concept of collecting data from data sources that offer a different angle to the research (Baarda et al., 2010:188). For this research it meant that not only actors from e.g. the grid operation sector, but also electricity suppliers, manufacturers and government officials were interviewed. For this study, I acquired an internship in a company that is involved as an advisor for several actors in the EV sector. Besides this, my supervisor is chairman of NEN NEC 69, the Dutch standardisation committee for electric vehicles. This proved to be a great starting point to acquire the willingness of organisations to participate in this research. Eventually, it resulted in an amount of 17 interviews, including one pilot interview. These interviews took between 50 and 70 minutes.

The following main topics were addressed during the interviews with each participant (a complete example can be found in Appendix F):

- The relation of the representative's organisation with the Dutch charging infrastructure.
- The process of standardisation and its implication for future developments.
- The developed standards and their impact on innovation.

All but one of these interviews were recorded and transcribed. Through an iterative process, categories and labels were devised and quotes were classified to these codes. As an additional layer, the data was used to build a historical overview of the facts, described by the interviewees. This text was e-mailed to the participants for extra feedback and approval of the description of events. This result is reported in section 5.1.

In qualitative research (like this one), the boundary between raw data and analysis is less clear than in quantitative studies. Along the data collection, the results were continually adjusted, according to novel evidence and fresh interpretation of events through new interviews. Still, a separation of results and analysis is possible by firstly presenting the data as factual as possible and only in the analysis part attaching meaning to it in relation to the theoretical framework. For this thesis, it was chosen to use a chronological description of the data (see section 5.1) and personal reports from interviews, divided into the following types of organisations: incumbents, newcomers and facilitators (see section 5.2). In total, chapter 5 serves as a context for the analysis in chapter 6. The conclusion can be found in chapter 7, which includes the answers to the research questions. Finally, in chapter 8, this study is discussed and recommendations are offered for future research.

5. Results

This is a description of the development of the EV charging infrastructure sector in the Netherlands, based on 17 interviews with stakeholders. These interviews were taken in the period between 22 February 2012 and 2 May 2012. In addition, information from news articles and weblogs was collected to round up the historical context. Combined, section 5.1 will guide you through the (quite recent) history of building and standard-setting of infrastructure for EV charging in the Netherlands. In paragraph 5.2, the focus is on the input of the interviewees and their opinions about innovation, standardisation and infrastructure.

5.1 The Historical Context of Charging Infrastructure in the Netherlands

The roots for the Dutch infrastructure, that allows electric vehicles to charge, can be traced back to 2008. Using a sports analogy, I divided the context into 'On Your Mark' (describing the first steps toward a new development), 'Get Set' (illustrating the preparations for a nationwide charging infrastructure) and 'Go' (portraying the launch of the market model and upcoming challenges). For additional information about technical terms or abbreviations, see the glossary (see p. 42) and the appendices A-D (see p. 46).

5.1.1 On Your Mark (2008-2009)

In 2008, the electrification of mobility was fairly limited to bicycles, scooters and industrial vehicles like forklifts. However, history showed that a consumer market might exist for electric cars. In the US, under the governmental pressure of California, General Motors (GM) started with the production of personal electric vehicles in 1998. The EV1 was the result and GM started to lease this car to the consumer market, where it was received with great enthusiasm by (rather wealthy) people that are concerned about the environment. Charging of these vehicles happened at home only (see Box 1). However, while producing and leasing the EV1, the automobile industry fought heavily against the Californian law that forced car builders to commit a growing percentage of the production line to vehicles without emission. Eventual, the law was abandoned and GM pulled back their EVs. [5]

Box 1. Origin of EV charging

In principle, car manufacturers were used to act alone. Their solution was initially that EV owners just should charge their car at home. So, they built their cars with internal chargers and provided plugs that could fit the standard domestic outlets. However, the charging speed was relatively low and these plugs were never designed to charge for example a Tesla Roadster repetitively for 14 hours.

While the EV1 was lost, the people building it started a new project, independent of any existing car manufacturer: Tesla. In the same time, the EV produced by Ford, the TH!NK, was rescued from the same fate as the EV1 by Greenpeace and moved to Norway (Greenpeace, 2004). Here, the new company Think Global AS produced the Think City. In addition, local car builders in the Netherlands began to convert existing cars, like the VW Golf, to electric variants. This all was possible because development in the laptop sector made batteries better

[5] See for more detailed information the documentary "Who killed the Electric Car?" (Pain, 2006)

and cheaper. However, besides small local initiatives, the Netherlands did not have a major car industry. All key manufacturers for vehicles were located in Germany (e.g. BMW and Daimler), France (e.g. Renault and Peugeot), USA (e.g. General Motors and Tesla) and Japan (e.g. Toyota and Nissan).

Noticing the trend toward electrification of personal cars, Dutch energy companies saw new potential for their business. However, one threshold was the fact that only 35% of all households in the Netherlands have the option to park their car in a garage or carport on their private property (CBS, 2009). The majority of car owners park their car in the public area, which formulated public charging infrastructure as a main concern for organisations that wished to make electric vehicles a success.

The Dutch energy supplier, Eneco, was the first company that put a public charging station in the ground. Their NRGSPOT had a long R&D phase and was placed in Rotterdam on 30 October 2008 (Eneco, 2008).

Figure 4. CEE plug (IEC 60309)

In 2008, there were practically no standards for charging electric vehicles. In the IEC (International Electrotechnical Commission) some old technical standards for the communication between a vehicle and a charging station existed, because of its history in industrial mobility. But questions about the safety requirements, type of plugs and sockets and how customers should pay for the electricity could not be answered by formal standardisation committees. In fact, the NRGSPOT was build according to the existing norms of a household meter, which made it quite large. It supported industrial plugs (fig. 4) which was used by EV converting companies and the electricity used for charging was provided without required payment.

The next milestone for electric transportation was the announcement about the release of the Tesla Roadster, an electric sports car (AutoWeek, 2008). Finally EVs from different manufacturers, like the Tazzari Zero and the Think City came to the Dutch market. In 2009, the Dutch government was approached by entrepreneurs, that wished to build a market for EV charging. For a country, the transition toward electric mobility has several benefits. It would reduce the countries carbon footprint and would allow less dependency on foreign oil. Next to this, the transition would support the economy by attracting car manufacturers for pilot projects and give rise to new ventures that could benefit from a new market, which enables growth in employment. This all resulted in a plan by the Dutch government to support the transition to electric mobility (Rijksoverheid, 2009). The Formule E-team was established within the ministry of economic affairs. This team could take care of publicity in media and investigate (tax) benefits for EV drivers (Rijksoverheid, 2011).

Figure 5. Schuko plug and socket (CEE 7/4)

Independent of the national government, the municipality of Amsterdam started its own EV project, which had the goal to improve the city's air quality. In November 2009, Amsterdam installed their first public charging stations in collaboration with the Dutch energy supplier Nuon and property developer Heijmans. The technical term for charging station is actually EVSE (Electric Vehicle Supply Equipment), because these charging stations do not 'charge'. The charger is built within the car and EVSE only supplies electricity. As with the case of Eneco, because of lack of clear standards, the EVSE manufacturer CoulombTech (US) was contracted to place charging stations with CEE Schuko plugs (fig. 5). The Amsterdam action plan (Amsterdam, 2009:9) expressed: *"Standard recharging relies on the regular 230 volt supply and a regular household power point, while 'rapid recharging' requires a higher voltage. In the short term, rapid recharging technologies are not an option for general use."*

However, European car manufacturers recognised that there might be a better solution than using domestic plugs for charging. Especially, because the European power grid differs substantially from the power grid architecture used in the US or Japan. In Europe, most countries support three-phase electricity at street level, which allows more power and thus faster charging. But this would require a different connector than used by US an Japan car manufacturers. On 22 September 2009 during an EV symposium in Sacramento, a presentation was held by Daimler and BMW, which included a concept for one universal EV connector. The design for this connector was based on a consensus about EV requirements by a workgroup in which also a Dutch grid operator (Enexis) took place (Oestreicher et al., 2009). In this symposium it was also proposed to use sockets at charging stations, instead of fixed cables (see Appendix C: Charging Types for this harmonisation proposal).

One more thing happened in 2009 that would define the standardisation course the Netherlands would follow: the foundation 'E-laad' was established. Grid operator Enexis was one of the organisations that in 2008 already defined a vision about electric vehicles. They formulated the 2050 vision of a world in which sustainable energy production and using the batteries of EVs as a buffer comes together.

First, this vision was demonstrated. Enexis put public charging stations in Den Bosch that could be controlled from a distance and be granted access using a RFID card. Logica provided these first prototypes. Second, the vision was communicated to other grid operators in the Netherlands. The idea was to start together a foundation (E-laad) that puts 5,000 of these 'smart' charging stations all over the Netherlands on public grounds by the end of 2012. The choice was made to provide AC standard charging. This specification for supplying electricity fit to the existing activities of regional grid operators. The charging stations were monitored carefully to provide an analysis towards the impact of EVs on the power grid. The charging stations were provided for free to municipalities and EV owners (on public ground). The idea was embraced by all Dutch grid operators, except one: Stedin, the grid operation organisation of Eneco (not uncoupled[6]) did not collaborate.

5.1.2 Get Set (2010-2011)

While being in the hands of grid operators, which is a public task, the foundation E-laad had to be careful about the public money it was using for building charging infrastructure. Initially, two independent EVSE manufacturers were contracted, Alfen ICU and Chargepoint. Later in 2011, the French manufacturer DBT would join for 350 charging stations. All the units that these manufacturers delivered to E-laad had to be controlled and monitored by a managing central system. Three manufacturers would have meant three different communication interfaces, a situation not very efficient for E-laad. Therefore, they developed together with their software partner Logica (who also wrote their managing central system) one standard interface. Now, every manufacturer who implements this protocol in their charging stations could communicate with the managing central system of E-laad, without extra software changes. This interface was named Open Charging station Protocol (OCPP), an open standard under administration of Logica[7] and E-laad mandated that their suppliers would use this system. Other manufacturers implemented it as well, recognizing the benefit of such an open system for potential customers. 'Open' meant that access to the specification was granted to any organisation interested in it, although changes in the specification was under the control of E-laad only. When OCPP appeared in multiple tenders from energy suppliers and municipalities, a de facto standard seemed to be born.

Next to this, more need for standardisation rose: multiple firms developed plans to provide charging solutions for EV drivers and different manufacturers began producing EVSE. In order to synchronise the efforts and preventing unnecessary incompatibilities between systems used in the Netherlands, the government's Formule E-team gathered market players to join a consultation about interoperability. This started the informal standardisation trajectory and was carried out through a multitude of consultation meetings. What was the case? In a study presented by TNO and Accenture, the market model for charging infrastructure was defined as a network model (Boekema et al., 2010; Accenture, 2010): The ownership of a charging station is uncoupled from the service that it can provide, which means that these new *service providers* could offer their charging service on multiple charging stations, which they *do not have to own*. This loosens the problem of monopoly, in which only an owner of a charging station could earn money and every company would have to place their own charging station. And because it's mainly on public ground, where permits are required and space is limited, such a *platform model* had in neither study the preference.

What did this mean in practice? The EV driver should pay his/her service provider and not the owner of the charging station *on the spot*. The idea was that EV drivers have a contract with such a service provider and then could identify themselves at the station and the provider would bill them afterwards. EVSE manufacturers were informed about this incentive and built

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[6] The Netherlands introduced in 2006 the WON, a law that determines that energy companies should be "uncoupled". Which means that energy supply and grid operation should not be managed by the same company. Eneco could postpone its uncoupling by fighting the law at European court.

[7] See http://ocppforum.net/.

in their equipment possibilities to identify users wireless. One solution was the RFID card demonstrated by Enexis and also Amsterdam used this system of identification. The problem: these cards did not interoperate. E.g. an EV driver with a card from E-laad could not charge at charging stations in Amsterdam, and a driver with a Nuon card from Amsterdam could not charge in any other city.

Eneco chose to implement the RFID technology of the Dutch Public Transportation Chip Card (OV Chipkaart) for their NRGSPOT as an identification technique for EV drivers. Their idea was that this chip card would be the main payment method for micro transaction in the future [8]. Therefore, Eneco invested in software links between Trans Link Systems (administrators of the OV Chipkaart) and in extra security, required for this RFID standard. However, these were additional costs that a majority of companies in the consultation group were not willing to make. Also, the use of OCPP drove the advantages of the Eneco system in the background. Eneco used the same technology as Trans Link Systems, whereby once per day all the data, that were collected this day, are sent to a central server in one package. This saved costs in terms of data transfer. However, OCPP required charging stations to be online permanently (e.g. so that service providers could distribute live information about the availability of charging stations). Eventually, a majority of EVSE manufacturers chose for equipment that was online continuously and could handle OCPP.

Next to this, there was still the incompatibility case with physical sockets that manufacturers used in their charging stations. Some stations had the CEE socket, used by car manufacturers ECE and Think. Other stations had Schuko, supported by Tesla and electric scooters. And then there were stations that had a new design used by Volkswagen, from the German firm Mennekes: VDE-AR-E 2623-2-2.

Figure 6. Mennekes/VDE Type 2 VDE-AR-E 2623-2-2

In the informal standardisation trajectory, during the consultation meetings, the advantages [9] of this new socket became clear. EVSE manufacturers, which had contacts within the automobile industry, recognised the potential future for this type of connector (fig. 6) and as one manufacturer said: "*But there is one thing worse than not to choose the best plug, that's to choose no plug*." In April 2010, the different organisations agreed to use the VDE socket (later known as Type 2) for all new public AC standard charging stations in the Netherlands (Rijksoverheid, 2010).

[8] Unfortunately for Eneco, Trans Link Systems never got the permission by DNB (De Nederlandsche Bank) to use the OV Chipkaart for micro payment transactions. In addition, Trans Link Systems got embarrassed by revealed security breaches in their card technology in the Dutch media.

[9] One main benefit of this type of connector is that it allows communication between car and EVSE. This enables "mode 3" charging, whereby there is no flow of electricity until the car and EVSE are correctly connected.

However, driving cars is not limited by national borders and questions arose about a future in which EVs would drive all over Europe and their need to charge everywhere. This is where the Dutch formal standardisation institute NEN NEC (see Box 2) became involved. With financial support of the Dutch government, the Netherlands became active in the international standardisation of Electric Vehicles: 'Normcommissie 364 069 (NEC 69) Elektrische voertuigen'. This in order not to isolate itself in Europe, but to follow the international development. The members of this commission were direct stakeholders in charging infrastructure. Important to notice is that the financial support of the government meant that members did not have to pay their annual contribution fee until January 1st, 2012. A total of 41 representatives responded to this offer. This started the formal standardisation trajectory.

Box 2. Formal standardisation

Formal standardisation takes place on three levels: international, continental and national. On international level, technical committees are installed, which have possible counterparts on the lower levels. For example: The IEC/TC 69 (International), CLC/TC 69X (Europe), NEC 69 (the Netherlands). A country can choose to become involved in the standard-setting process by taking up such a national counterpart committee. This allows a country to raise a voice within international standardisation processes.

Initially, three working groups were chosen: (1) Focus on plugs & cards. (2) Focus on protocols between charging station and managing central system and in-between managing central systems. (3) Focus on possibilities for paying at charging stations. However shortly afterwards, these were reduced to two working groups: (1) Plug & charging station and (2) Communication.

The NEC 69 had the choice between publishing a norm or publishing a NTA (Dutch Technical Agreement) to formalise agreements. The latter had the advantage of being able to be realised relatively fast, in contrast to norms, that usual take 2-3 years until approved. In working group 1, it was decided to work on a NTA about charging electric vehicles: EVSE-plugs and EVSE-sockets. Here, the choice for the VDE socket (Type 2) that was made during the interoperability consultations was confirmed and an assignment was given to translate the German norm VDE-AR-E 2623-2-2 in Dutch. The scope for this NTA: Public AC charging stations.

Figure 7. The CHAdeMO plug

In May 2010, the first public DC charging station in Europe was revealed in Leeuwarden, the Netherlands. This allowed EVs to charge with a higher charging speed and was earlier used to charge industrial vehicles, like forklifts. However, there was no mass-produced personal car on the market, that supported a standard for this kind of charging. This changed in October 2010, when Mitsubishi presented their standard for this type of charging on a tradeshow in Paris: CHAdeMO (fig. 7). With this protocol it was possible to charge electric vehicles (equipped with CHAdeMO) with up to 50 kW direct current, which allowed a higher charging speed. Therefore, this kind of charging stations were often referred to as Fast or Quick Chargers. However, it would take until the end of 2010 until the first cars arrived in Europe that supported CHAdeMO. Starting in 2011, all new public DC charging stations supported this CHAdeMO protocol. Manufacturers of these charging stations could adapt to this standard even before any car was launched on the market. So, once on the market, the charging stations were finished and deliverable.

In the mean time, public AC stations were installed according to the new Type 2 standard and E-laad started to convert its original stations to the chosen standard. An indication of how early the Netherlands were with this decision is the story about the first certified Mode 3 Type 1/ Type 2 cable (see Box 3).

Box 3. History of the Type 1 / Type 2 cable

When Nissan wanted to sell their first electric vehicle in the Netherlands, a charging cable had to be provided. This to connect the Type 1 socket in the car to the Type 2 sockets that were now standard for public AC charge points. This was new, because car manufacturers were used to deliver only cables with domestic plugs, so that people could charge at their homes. A Dutch service provider promised to take care of the problem. However, nowhere in the world existed a certified Type 1/ Type 2 cable. In collaboration with other companies and even the Dutch government, a certified cable could be realised. Just in time before the launch of the Nissan Leaf.

From time to time, the charging of electric vehicles experienced problems. What was the case? The Mode 3 protocol that was defined by the IEC, allowed a certain degree of freedom in its implementation. That this would lead to practical problems was found when car manufacturers and EVSE manufacturers implemented Mode 3 separately, trusting on the IEC norm. However, there was room for interpretation about the time span the car and EVSE had to wait before connection was confirmed or denied. Sometimes, this led for the car or charging station to 'time-out' and no electricity was provided: the charging failed.

This and other problems, experienced by manufacturers about the Mode 3 protocol, led the IEC to review its norm and an improved version is expected to be released in the future. Would this mean that all charging stations that were already installed would need to be physically visited and the control chip to be replaced? Luckily not, smart manufacturers implemented a central server for their EVSE, where the software was managed and could be accessed by internet. This 'cloud' allowed manufacturers to reprogram the Mode 3 protocol, without physical visits (which would require extra manpower and capital). Background of this decision to use a cloud is the expectation that the communication protocol is about to change a lot more in the future, eventually making it possible to enable identification and billing by the car. This required flexibility in the infrastructure and was handled smartly by manufacturers that were conscious about this development.

Meanwhile, the informal consultations continued and on 18 February 2011, six market players signed the interoperability contract on which they worked during 2010. Now, all RFID cards that these market players provided to their customers could be used on each other's charging stations. Notable: at this time, this was done by formulating a 'white list' with card IDs, inside the CIR database (Centraal Interoperabiliteits Register)[10]. Here, managing central systems of the individual companies could login to retrieve if a card ID was 'white listed', thus registered by one of the companies in the CIR. If that was the case, the customer could start charging his/her EV. At this point, no fees were asked for these transactions, neither to the customer, nor to the service provider. This would require another set of standards, which development efforts increased due to an important decision by the Amsterdam pilot project.

At this point, Amsterdam, who ordered a large set of charging stations from Nuon and Essent, financed the electricity that was delivered by these points. However, right from the start of the project it was made clear that this would stop per 1 April 2012. This accelerated the development of a working market model, because one essential part of the model is to settle the transactions between the providers.

In May 2011, the interoperability consultation was heading to a new level. Under the finance of the Dutch government, the association of energy network operators and the association of energy suppliers, the consultation was brought to an independent process and project facilitator (P2) and was renamed 'marktpartijenoverleg' (market consultation). This platform was used to tackle day-to-day practical problems, identify obstacles in the market and make settlement between service providers and charging station operators possible. In the transition between the interoperability consultation (Formule E-team) and the market consultation (P2), the industry association DOET played an important role in formulating and structuring working groups for their members, that were implemented by P2 eventually. The association DOET was founded in June 2010 for all kind of electric transportation and increased in importance with the introduction of personal electric vehicles.

Back to the formal standardisation inside the NEC 69. On June 1st 2011, the NTA 8623 was published. With this official agreement, the Netherlands conform itself to the Type 2 Mode 3 charging connector and protocol for public AC charging. This made the Netherlands one of the first countries in Europe that officially supported Type 2. Not even Germany, where this standard was developed, agreed officially to use this type yet. But again, of all European countries, in the Netherlands the need of public infrastructure was felt most urgently, due to the fact that a majority of car owners have to park their car on public ground.

On 11 October 2011, the second version of the international norm about connector types for charging EV was published. It included a position paper from the ACEA (ACEA, 2011) whereby a recommendation for Type 2 Mode 3 for public AC charging infrastructure was made. Now it was official that Type 2 is supported as an international standard. At this point, more than 800 charging stations in the Netherlands were already installed with Type 2 by E-laad (E-laad, 2011).

More players came to the market, due to the established clarity regarding the type of EVSE connectors and because of the existence of an open protocol for communication between charging station and managing central system. The energy supplier HVC, was one of the first commercial organisations that required EVSE manufacturers to include OCPP in their services. Now, HVC could offer their shareholders (which are 52 Dutch municipalities) charging stations

[10] The CIR was developed with the same technology as OCPP and the backoffice system of E-laad, namely by Logica.

from diverse manufacturers without that the owner (which would be the municipality) had to develop new communication interfaces for different brands of EVSE.

Meanwhile another new market for EV charging was at the horizon. RWS, the governmental department responsible for highways and waterways in the Netherlands, was approached by the private sector about the possibility of selling electricity at rest areas along the highway. At this point, such a service did not exist in the legal matters of RWS. At rest areas you can (1) offer gasoline and (2) offer food/beverages at restaurants. However, RWS was willing to look into it.

5.1.3 Go (2012 and Beyond)

Starting January 2012, RWS' legal system could handle electricity as a third option for companies to facilitate on rest areas along the highway. Within 21 days, six organisations filed applications for a total of 459 charging stations that offer DC charging (Rijkswaterstaat, 2012). This would mean that a nation-wide network of DC chargers along the highway could be realised. One requirement of RWS was that these charging stations could be used by anyone, without having a contract with a Dutch service provider. Their argument is that foreign EV drivers, visiting the Netherlands, should also be able to charge their EVs along the highway, just as everyone is able to tank gasoline. It will be interesting to see what organisations devise to integrate this requirement in their business model, especially because existing (AC & DC) charging infrastructure was made available to customers only by contracts.

In April 2012, the service providers announced that they enabled a system that makes settlement on the basis of EV charging transactions possible. Right in time, as Amsterdam stopped subsidising these transactions. The protocols that make the settlement possible are now being discussed in the NEC 69, for a formal standardisation. E-laad stated that they stop providing RFID cards and that existing customers have to switch to another service provider by the end of the year. As a public entity, financed from grid operation activities, the role of service provider was too commercial in the eyes of the Dutch government. In the future, E-laad will focus only on the installation and operation of charging stations, which was their initial goal anyway. They had to take the role of service provider upon them, because no standards existed at the beginning of E-laad to uncouple service and operation of a charging station. They had to release RFID cards[11], so that EV owners could use their charging stations.

On a formal level, the Dutch technical committee NEC 64 developed a norm about requirements for special installations or locations and they included supply for electric vehicle (NEN, 2012). Furthermore, discussions took place about the technical committee NEC 57, which is responsible for power systems management and associated information exchange (NEC57, 2012). In fact exactly what happens between a managing central system and an EVSE.

Also, the first international agreements took place between European countries on the matter of AC public charging. Organisations from the Netherlands, Germany, Belgium, Luxemburg,

[11] Initial, E-laad asked EV owners a contribution fee of €100,- but this was abandoned quickly, after being criticised that as a public organisations (founded by regulated grid operators) they must not act as an commercial entity.

Austria, Portugal and Ireland decided to organise an 'international CIR': The open European Clearing House System, based on the Open Clearing House Protocol.

Meanwhile, Amsterdam finally replaced their first 100 charging stations (that were installed in 2009 with schuko plugs) with charging stations compatible with Type 2 Mode 3 (De Jong, 2012).

The Current Market Model

The network model and associated interface standards for public AC standard charging for the Netherlands as it is executed currently: (fig. 8):

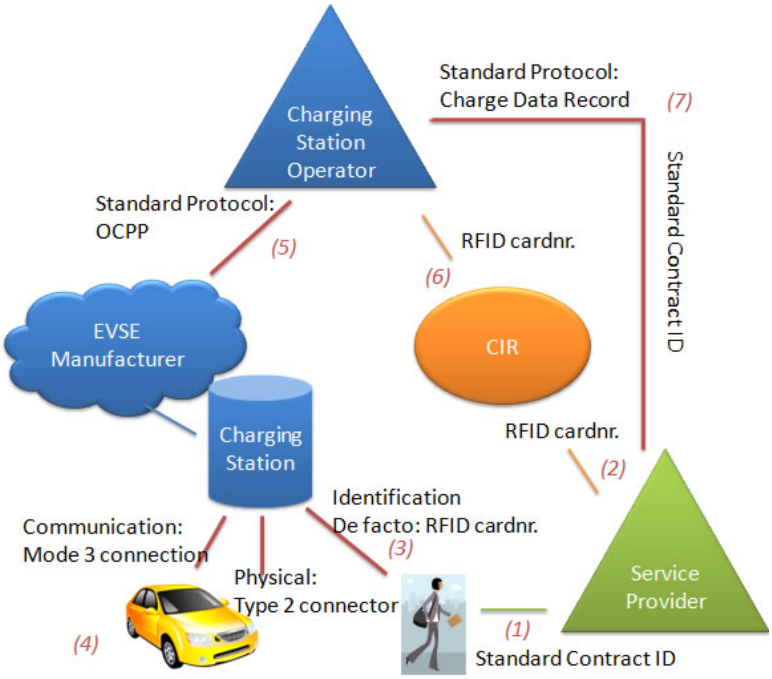

Figure 8. Interface standards for the current market model

(1) The EV driver can get a contract from a service provider. He or she receives a RFID card that contains a RFID identification number. The service providers couples this number to a contract identification number (Standard Contract ID) in their managing central system.
(2) The service provider sends the RFID card number (and possibly the Standard Contract ID) to the CIR (Centraal Interoperabiliteitsregister), where it is stored together with the service provider identity in a central database.
(3) The EV driver can enable a charging station by identifying her or himself by using the RFID card. The RFID card uses the 7 byte MIFARE classic standard for authentication. The charging station knows if the card number is registered in the CIR.
(4) The car can be connected with the charging station with a Type 2 connection cable. The charging station communicates with the car using the Mode 3 protocol. The car starts to charge.
(5) The charging station operator can either directly control the charging station, or do it via the software system of their EVSE manufacturer. OCPP defines the minimal set of

actions that a charging station has to be able of. For example that the RFID identification is approved, or the amount of energy taken by the EV driver.

(6) The charging station operator can collect RFID card numbers that are registered by service providers from the CIR database. This can be done real-time, every time when a EV driver wants to charge at their charging station through an internet (GPRS) connection. However, the RFID card numbers can also be saved in the memory of the charging station locally (or the EVSE manufacturer's cloud). Frequently, this memory can be updated manually or automatically.

(7) When the role of charging station operator and service provider are not taken by the same company, the settlement takes place using the standard protocol Charge Data Record. This record is coupled to a Standard Contract ID, which contains an identification code on which the service provider can find its customer (and bill her/him). This can also be done using the RFID card number. No direct contact information of customers has to be saved in the central sever, which is important for the privacy of customers.

Note: This model describes the transactions that start with charging an EV. The electricity production and delivery to the charging stations is excluded. Described here are the *roles* that exist in the model, whereby one organisation can fulfil multiple roles. An additional role, excluded here, is the role of ownership. Often the charging station operator is also the owner, but this does not have to be. It is possible that for example a municipality uses a charging station operator to build an charging infrastructure, but finances and owns the physical charging stations. The electricity bill of the energy supplier from which a contract is chosen goes to the *owner* of EVSE. From there it can go to the charging station operator, service provider and/or eventually the EV driver, dependent on the agreements made. In total, ten organisations in the Netherlands offer access to the public charging infrastructure, using this market model.

And the Future…

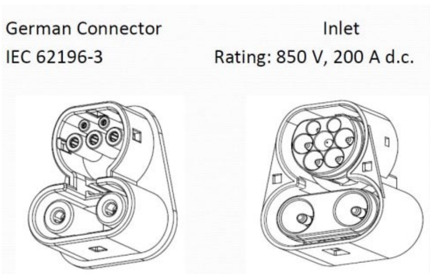

Figure 9. Mennekes Combo Type 2 AC/DC

An interesting development will be the competition of standards around DC charging. All DC infrastructure in 2011 was based on the CHAdeMO protocol, which was the only protocol supported by the EVs that were able to charge DC. However, in 2013, it is expected that the first wave of a new generation European electric vehicles enters the market, which supports an entirely different system: the Combo plug (fig. 9). It is based on the AC Type 2 connector, only that it allows DC charging as well. This allows car builder to integrate only one inlet in their EVs, in which AC and DC charging is possible. However, while 100% compatible with existing AC public infrastructure, the Combo device differs substantially from the CHAdeMO protocol, which makes compatibility with CHAdeMO unlikely. In addition, DC charging infrastructure requires a considerably higher investment than AC charging stations, which makes it more resistant to change. Nissan and Mitsubishi do not seem to let their CHAdeMO protocol to be substituted easily either: Nissan started to develop their own

CHAdeMO chargers and provides them for free all over Europe and the US (Herron, 2012). These chargers also include AC fast charging possibility, supported by Nissan's strategic partner Renault. In total, the following technical standards are under discussion: CHAdeMO (50kW DC), Type 2 AC/DC Combo (EU, >50kW DC), Type 1 AC/DC Combo (US, >50kW DC), Tesla Supercharger (US, 90kW DC) and AC Ready (EU, 43kW AC). All these techniques require different plugs, which are attached to the EVSE (due to the weight of the thicker cables, necessary for higher power levels). An interface format battle could be the result in the future.

Further, what path will the European Clearing House take? Until now, only two Dutch service providers have signed this treaty: will others follow? And will OCPP become an internationally accepted communication standard?

5.2 Standardisation of Innovative Infrastructure in Practice

This result section is dedicated to the opinions that interviewees mentioned about the impact of standardisation to an infrastructure that should support innovation. It also includes experiences from the history of the Dutch charging infrastructure, as described in the previous part. The results are grouped according to the following types of actors: Incumbents, Newcomers and Facilitators.

5.2.1 Incumbents (Energy Suppliers and Grid Operators)

The Netherlands has an area of total 41,543 km², from which 18% consists of water and is inhabited by 16.8 million people. The Netherlands are populated densely: 470 residents per km²; only 3% of the area in the Netherlands is used for working and living (CBS, 2001). These facts make it possible that a limited amount of energy suppliers and grid operators (both key players in the electrification development of transportation) can organise the production and distribution of electricity in the Netherlands. In total, there are nine grid operation companies and three major electricity producing energy suppliers (NMa, 2012).

For these energy suppliers, the additional consumption of electricity through the use of EV, is the main motivation to support the development of electrification of personal transportation. Should EVs become a success, they would receive extra revenues. However, the (human) resources that energy suppliers are willing to devote for this task are still small at this point, compared to other projects in the firm. EV charging projects are started by individuals who believe in the development and could convince their managers to allow them to spend time on an EV project. They have to face sceptics in their own company, a situation that differs hugely from that in companies that devote themselves entirely to electric vehicles (newcomers). However, an important advantage of energy suppliers is the availability of funds to spend time and money on formal standardisation. In addition, these large organisations are used to formal standardisation processes and take place in international or European standard-setting organisations.

Energy suppliers are commercial entities and the fact that foundation E-laad gave away charging stations 'for free', was highly bothering. Especially in the beginning of the EV development, energy suppliers saw a major threat in competition due to the fact that municipalities were not willing to invest in charging infrastructure, beyond the few stations that E-laad offered without payment. Eneco, for example, felt that the low adoption rate of their NRGSPOT was the result of the E-laad project.

Essent and Nuon forestalled this problem by initiating contact with the largest cities in the Netherlands in an early stadium. They acquired an exclusive contract for installing and maintaining charging stations in Amsterdam, even before E-laad was clearly in the picture. Nuon buys the charging stations from EVSE manufacturers and Essent develops their own in collaboration with their German parent company RWE. Both energy suppliers create revenues by installing and maintaining charging stations.

HVC, an energy supplier that produces electricity from waste, has municipalities as shareholders and offers them three charging stations per municipality for free as well. Their agreement with E-laad is that if one of their shareholders wants to have just one charging station, they should contact E-laad; if they want more, HVC offers an additional three and possibly more against cost price. These charging stations are then fully owned by the municipality, a difference with E-laad, which keeps owning and maintaining the charging stations themselves. HVC only generates direct revenues from the extra electricity that is used.

For grid operators, the electric vehicle presents an opportunity as well as a threat. Their role would be even more important to society when mobility depends on the delivery of electric energy. However, the impact of charging EVs on power grids is substantial and if unmanaged it could lead to troubles in delivery of electricity in the future during peak times (for instance, if EV owners arrive home at six o'clock PM and plug in their EVs simultaneously). Next to that scenario, there is the ongoing trend towards decentralised electricity production by photovoltaic panels at homes and sustainable energy supply by wind turbines. To use sustainable energy more efficiently, buffering is necessary (e.g. wind turbines: At night they produce an overcapacity and at peak times they produce not enough to meet demand). Grid operators wish to control the charging of electric vehicles. By doing that, they could potentially save investments in a heavier power grid infrastructure. However, in the Netherlands, grid operators are public organisations, regulated by the Dutch government. They have to justify investments to the Dutch Competition Authority (NMa) and by law are not allowed to carry out any commercial activity. Their lobby is to make electric vehicle charging a regulated task in the public area. That would mean they could use public money to make the investments and are in control of the charging (and possibly discharging) of EVs.

In the meantime, the foundation E-laad was created by an act of co-operation between grid operators. This project was financed by governmental subsidies and should give the grid operators a good overview of the impact that electric vehicles have on the power grid. Therefore, E-laad installed charging stations under their operation all over the Netherlands. This led to conflicts between activities in the grid operation regulation and the building of charging infrastructure in the public area. Grid operation is a public activity by law and charging station operation is seen as commercial domain. One perspective is to compare EVSE to electricity connections in households, whereby the grid operator is responsible up to and including the meter. In EVSE on public ground, usually a meter is placed as well, which would bring the EVSE under the responsibility of the grid operator. However, that would be commercial domain according to current law in the Netherlands. A different perspective is to see the EVSE separate from the power grid and the responsibility of grid operators end with the power connection to the EVSE.

5.2.2 Newcomers (EV Service Providers and EVSE Manufacturers)

An organisation can take the role of service provider to enable EV drivers to charge their vehicle at public charging stations. This is a commercial role. They receive revenues by selling contracts to EV drivers and give them access to charging stations in return. For service providers, it is essential that a public charging infrastructure exists, because otherwise their product is worthless. They experience the dilemma between the number EV drivers and the number of installed public charging stations at its core: driving electric vehicles only makes sense when an adequate charging infrastructure exists, but investment in infrastructure only makes sense when consumers drive electric vehicles. The 'chicken-or-the-egg' problem.

This investment in infrastructure is felt to be crucial for the survival chance of newcomers. Interviewees agreed that investment should be as low as possible, but it should still guarantee a working infrastructure. The following ideas were pronounced by respondents:

(1) Infrastructures should be compatible with each other, so that a nationwide infrastructure could be realised in a competitive, but also collaborative way.
(2) Components in the infrastructure should be as cheap as possible.

One of the first EV service providers in the Netherlands was The New Motion (TNM). They started as a very small company (three employees) to offer general services for EV drivers, like advisory. When EVs became more popular, TNM recognized they could fulfil an all-in-one solution for EV drivers. They initiated collaboration with car dealers and lease companies to offer EVs. They began to install charging stations at home and at the work of EV drivers. Also, they started to build a public fast-charge infrastructure. They actively participated in the standardisation process, both formal and informal, to ensure an infrastructure compatible with other service providers. But above all, they watched out that no needless costs would be necessary to conform to EVSE standards. In their need to be as cost-efficient as possible, TNM decided initially to develop their own charging station, rather than buying them from external EVSE manufacturers. Their opinion was that it had to be possible to produce cheaper charging stations than offered by the market at that time. By doing so, they also took the role of charging station operator and EVSE manufacturer. For these newcomers, building the charging infrastructure benefited from the informal standardisation trajectory. Meetings between market players in informal settings were used to identify problems in the development of the Dutch charging infrastructure. These problems were daily, practical matters, but also long-term issues that were concerned with bringing the network model (see p. 2) into practice. Solutions to these long-term hurdles resulted in de facto standards that made compatibility and settlements between service providers possible. The formal standardisation process through the standard-setting body NEN was perceived differently by these stakeholders. As some interviewees mentioned, this process differed enormously from the informal process they were used to. For them, it was experienced as slow and full of technical aspects.

As a charging station operator, an organisation is responsible for the (correct) function of a charging station. To do this job effectively, communication with the charging station is essential. As a charging station operator an organisation can be in control of charging stations from different manufacturers. E-laad expressed the wish to avoid 'venture lock-in': the necessity to constantly use the equipment from one, single manufacturer. Therefore, OCPP was developed as a mandatory communication standard for EVSE manufacturers that wished to offer their product to E-laad. According to interviewees, the idea behind OCPP is gaining a lot of attention in the world and it seems to become a de facto standard. But, in the end, this does not have to be the exact protocol that is developed by Logica for E-laad. It is the philosophy behind it, the enabling factor to overcome venture lock-in, which is the important criteria. As one consultant noted: As soon as a couple of manufacturers adopt the same protocol, the operator always has a choice.

It is unlikely that an organisation can earn revenues by being only a charging station operator. The reason E-laad is able to do it is because of its public nature: financed by grid operators. Also municipalities can allow themselves to finance the charging station operations because they are public bodies. Both activities are heavily subsidised. Reason to do this is to solve the chicken-or-the-egg problem, as explained on the previous page. However, combined with the role of service provider, the operation of charging stations can be profitable. The New Motion is an example. But again, to be profitable, the chicken-or-the-egg dilemma has to be solved first. This is where public activities come in the picture.

Manufacturers of charging stations also see electric mobility as the key innovation. However, their incomes are directly based on the building of an infrastructure that involves putting charging stations in the ground throughout the country. They compete with other EVSE manufacturers, which let them strive toward product innovation which reduces costs and/or offers additional services.

For EVSE manufacturers, expected changes in the communication protocol standard between EV and EVSE had an important impact on the design choice of their charging stations (see quote 1).

Quote 1. EVSE manufacturer

> *"That's why we said, the only EVSE that we put in the market is an online charging station that is always reachable. One thing I am sure of: the standards and what you want to do with it, they will change. Later on, the cars will communicate in a certain way to pass through the state of charge, which is incredibly important for smart charging. When this occurs, we implement it in the charging station, adapt the software and send the software update to our network and all charging stations work. So, that is our way to protect us against changes in standards."*

A new development EVSE manufacturers fear, are upcoming certification standards from car manufacturers. Experienced incompatibilities between charging stations and electric vehicles lead to certification efforts by e.g. Renault to make sure that a charging station is built and installed according to Renault's guidelines. A development that would lead only to frustrations and higher costs for infrastructure, as said by multiple interviewees.

5.2.3 Facilitators (Government and Consultants)

Convinced about the benefits promised by electric mobility for a country, the Dutch government played a facilitating role. The goal was to become a frontrunner in Europe on the area of EV. The innovation of EV was supported in two complementary ways: informing the public and assisting the development process. A guidance for the standardisation of charging infrastructure was chosen carefully, because as one interviewee mentioned: *"We do not possess the full wisdom to ensure that choices are correct on the long-term. It should be developed by the market, not the government"*. Their opinion was to assist as much as possible, without changing too many laws and regulations. Also, they made sure not to formulate a preference for a given technology. This was experienced as frustrating by some commercial stakeholders, who wished to have a picture as clear as possible about the Dutch EV development. Also the wish of grid operators to include public charging infrastructure in their regulated task was opposed by this stand of the government.

In order to streamline the efforts of companies for an EV market, the Dutch government, represented by its established Formule E-team, organised meetings for stakeholders. Their opinion was that problems should be solved in a structured, collective way. In cooperation with the industry associations of energy suppliers and grid operators, they financed an external consultancy as facilitator in the process. This support was guaranteed until the end of 2012. Agreements in these consultations could be seen as informal standardisation.

The involvement of the government in formal standardisation was initiated by the insight that the Netherlands is a small fish in the global pond of EV development. The fear was to be isolated in Europe, by creating a national lock-in for charging EVs. Especially, because then, support from foreign car manufacturers would be all but certain. So, involvement in international standardisation had to be pursued (see quote 2).

Quote 2. Consultant

> *"I was involved in the creation of that standards committee [NEN NEC 69] right from the beginning, that was two years ago. Then, I had contact with one of the groups established by Economics Affairs and the Ministry of Transport. There it was admitted that the role of standardisation is quite crucial to the success of electric vehicles. If everyone is going to offer their own infrastructure, it will never be a success and we might as well stop; that was recognised. Also, I held a passionate plea for linking the standardisation to European and international developments. This was not the case at that time. That idea was embraced, luckily. And so, shortly afterwards, supported by the Ministry of Transport, the standards committee started."*

The government financed the start-up of the technical committee and provided free memberships to organisations. This was embedded in the standard-setting body NEN, which holds associates to academic research through the Chair for Standardisation at the Rotterdam School of Management of the Erasmus University. Nevertheless, in the technical committee itself no academic research was represented directly through membership. However, private consultancy companies and research firms took place as members, next to manufacturers of EVSE. Another impact of the government policy was their assignment to investigate solutions toward the monopoly problem of charging stations, as mentioned in the introduction and problem description of this thesis.

6. Analysis

The analysis in this chapter uses the sensitising concepts from the theoretical section. The facts and opinions from stakeholders in the result section are related to these concepts, in order to explain what consequences the standardisation practice has on the innovativeness of the Dutch charging infrastructure. The first paragraph is about implications from historical facts of this case and properties of the Netherlands. The final two paragraphs in this analysis are about the standardisation process and the types of standards that were developed.

6.1 Analysis of Historical and Country-Specific Aspects

This part describes aspects of the Dutch charging infrastructure standardisation case that do not have a direct link with theory, but were found in the interview results of Dutch stakeholders. These aspects are important, because they describe the context in which the standardisation process took place. By analysing the results, I recognised three aspects that influenced the standard-setting process and identified them as 'Small amount of players', 'Car industry independency' and 'Leader in Europe'.

Small Amount of Players

The Netherlands has a limited amount of energy suppliers and grid operators, which organise the production and distribution of electricity in the Netherlands. The foundation E-laad represents a common goal of a majority of Dutch grid operators and was relatively easy established, because there are only nine grid operators in the Netherlands. In other countries, such a collaboration is less obvious. For example, Germany has about 700 grid operators. Including E-laad, there are about ten organisations in the Netherlands that make agreements on the execution of the market model and the interface formats that should be used. While it may not have influenced the choice for a specific technology per se, having a small amount of players certainly sped up the process of decision-making.

Car Industry Independency

As mentioned in the results, the Netherlands does not have a significant sector for the manufacturing of (electric) vehicles This fact makes it possible that their national standardisation decisions are not perceived as commercially-motivated threats by car manufacturers. The Dutch choices for charging infrastructure are not actively influenced by a national car industry and thus perceived as an objective selection of the 'best' technology. Unable to play an active role in the technological development, stakeholders in the Netherlands were more cautious about the standardisation. They knew that international developments had to be followed closely to prevent a national lock-in. Representatives of car manufacturers used the initial free-of-charge opportunity to join the formal standardisation committee NEC 69, but as other members of the committee mentioned: these representatives only listened and learned about the Dutch developments. They did not try to influence it.

The factor of being independent from the car industry might not have influenced the content of agreement, but it helped in the acceptance of the agreements on international scale. There was less danger of being overruled, guided by competitive arguments from firms in other nations, that possibly would feel threatened by lobby-actions for national standards from competitors (see e.g. Shapira and Varian (1999)).

Leader in Europe

The Dutch government presented a strategic formulation of pursuing leadership in the development of a national charging infrastructure (Rijksoverheid, 2009). Suppose, the standpoint of companies and the government would have been to wait until all standards were developed and actively adopted; then the Netherlands would be a clear follower in the development of electric transportation. According to the interview results, the disadvantages would have been missed opportunities for the business community in the Netherlands and delay or even rejection of the transition toward electric mobility by the society. It seemed that these disadvantages outweighed the disadvantage of having to handle the uncertainty that is presented by choosing leadership in the commitment to standards.

The problem for standardisation is manifested by the choice what to standardise formally and what to leave open. By making use of professional knowledge from individuals, involved in the international EV development, it could be determined in the technical committee which technical solutions are mature enough and have the highest chance of adoption in other countries. In addition, it was cautiously considered what components actually need to be formally standardised. A smart method was to use the NTA (Dutch Technical Agreement) concept, whereby relatively quick decisions could be arranged formally, but which also could be abandoned rather swiftly, if necessary. By doing so, organisations not involved in the initial decision process could be pointed towards this formal agreement, when looking for standards for charging technology. Newcomers could use this formal document to learn about the official technical standards and technical incompatibilities with the incumbent system would be avoided. Plus, the NTA could serve as a reference in tenders and for potential clients. In literature, alternatives for formal standards within standards-setting bodies (such as NTA) seem to be underexposed. They offer a faster pace of standardisation, which speaks more to the nature of SMEs. Because such agreements are less strict than norms, more flexibility is offered, which is experienced as beneficial for innovation.

6.2 Analysis of the Standardisation Process

In this section, the policy recommendations of Swann (2010) are used to describe the standardisation process and its implications for innovation. This is based on interview results from actors that were involved in the process.

Engagement of Stakeholders

In the Netherlands, engagement in standardisation was achieved on two levels: informal and formal. Firstly, the government Formule E-team organised meetings with organisations involved in building charging infrastructure. This can be seen as the informal standardisation process, because no formal standards-facilitating organisation was included. The meetings were used to identify and solve common problems and let organisations work together. Especially SMEs liked this pragmatic standardisation process, because they benefit from the increased pace of the development in charging infrastructure. For innovation, the informal engagement of stakeholders meant that (new) SMEs were involved, which defended the stakes of smaller companies. Innovation is supported through this engagement because new companies promise innovativeness (Baron and Shane, 2007).

Secondly, the Dutch government supported the initiation of a formal technical committee within the standard-setting body NEN. This was financially support and allowed members to join the first year without paying the otherwise mandatory contribution fee. This ensured a broader involvement of stakeholders. Especially SMEs used that opportunity to join. However, after contribution fees had to be paid, a majority of these companies left the committee. This could mean that the costs of being involved did not outweigh the benefits. Particularly, since the informal consultations still existed as a free way to be involved in the infrastructure development. Overall, the informal process was felt to be much more constructive than the formal process. For innovation, the formal engagement of stakeholders meant to place the Dutch developments in an international context. Goal was to prevent a national lock-in, which would reduce the chance or pace of adoption of international innovations in EV charging technology.

Updating the Stock of Standards

At this time, the stock of formal standards in Netherlands concerning charging infrastructure is fairly limited. The NEC 69 published one norm about AC charging stations (NEN-EN-IEC 61851-22) and one NTA about EVSE sockets in public areas (NTA 8623). However, it is expected that changes will take place in the communication protocol between EV and EVSE, which would require updates in the norm. In addition, it is likely that the NTA will be replaced by an official norm in the future. In the meantime, NEC 64 developed a norm about requirements for special installations or locations and they included supply for electric vehicle (NEN, 2012). Furthermore, the NEC 57 is responsible for power systems management and associated information exchange (NEC57, 2012), which in fact is exactly what happens between a managing central system and an EVSE. OCPP is a protocol about this information exchange, which would make formalisation through this technical committee a logical choice. However, as mentioned in the results, most stakeholders are or were active in the NEC 69. Plus, information exchange protocols are discussed in the international counterpart of NEC 69 as well. Another challenge is the fact that many agreements are made on an informal basis and only some agreements are formalised by the NEN institute. That is the reason, the NEN institute would be unable to provide a complete stock of standards. They would only cover the formalised agreements. An updated stock of standards for charging infrastructure could be helpful for innovation. Charging station manufacturers would be encouraged to use state-of-the-art technology and their products would stay compatible with the rest of the infrastructure.

'Big Issues'

The 'big issues' that were in mind of stakeholders had a great influence on the development of the Dutch charging infrastructure. For grid operators, the big issue at hand for charging electric vehicles was the idea of using battery capacity of electric vehicles as a buffer for sustainable energy and creating a 'smart grid', which could save grid operators large investments in grid capacity. Therefore, technology that would support smart grid and smart charging of electric vehicles had to be pushed. By creating the association E-laad, a public charging station operator was born which would support the charging technologies that were beneficial for the big picture that grid operators had in mind. As E-laad pronounced their goals about a national public charging infrastructure and indeed became a dominant player in building the Dutch charging infrastructure, their technological choices were soon to be regarded as de facto standards.

While SMEs had the focus on increasing the pace in development, large firms like the grid operators focused on the long-term and made sure that the development would at least not result in a technological lock-in which would disturb their long-term view. As the example of Amsterdam showed in the results, it was not unthinkable that a national charging infrastructure could have supported the domestic Schuko socket. Amsterdam was the first municipality in the Netherlands, which embraced the idea of investing in a large infrastructure of EV charging stations. In an early action plan, Amsterdam argued for the use of the Dutch domestic household socket (Amsterdam, 2009). This meant EVs started charging immediately when plugged to the charging station, with a voltage of 230V. All EVs supported this socket and Amsterdam was initially the dominant player and set an example. However, this example did not fit in the large picture of integrating EVs with the power grid, which required a different socket. For innovation in charging infrastructure, it is important to know the big issues at hand in order to prevent technological lock-in.

Integration with Research and Innovation

For the formal technical committee, links with research are provided through the standard-setting body NEN, which holds associates to academic research through the Chair for Standardisation at the Rotterdam School of Management of the Erasmus University. In the technical committee the Dutch organisation for applied scientific research (TNO) holds several links with universities. In the informal standardisation process, links to R&D are provided by the suppliers of the EV service providers. For literature, a distinction might be useful between links to universities in formal standardisation and links with R&D in informal standardisation. At least for the Dutch EV case, this distinction can be made for integrating research and innovation with standardisation. Next to this, governmental policy was to support a few stakeholders by financing studies about research topics of their choice. However, this support was not explicitly related to standardisation.

Access to Standards and Pricing

The formal standards about standardisation can be bought easily from the websites of the NEN or IEC. Prices or access to these norms were never mentioned as problems by stakeholders. However, there exist a couple of informal agreements between EV service providers and access to information about these agreements is less easily. One had to be participant in the market consultations that were organised by the Formule E-team, in order to be fully up-to-date about the agreements and solutions for incompatibility problems. As all stakeholders that were interviewed took part in this consultation or at least were aware about its existence, it is not surprising that this was not declared as a problem. Nevertheless, from an innovation perspective, equal accessibility to standards for newcomers and incumbents could be beneficial. Therefore, a task could be to either formalise all informal agreements, or to guarantee in a different way that access to this information is not excluded for new players in the EV charging market in the future.

Coordination of Different Government Activities

The Dutch government wished to present itself to be supportive, but not decisive for a national charging infrastructure. Policy was to support all different sort of activities of stakeholders. This was done by financing facilitators for meetings, studies and standard-setting. The main idea was to let the market decide on agreements, as for example compatible charging infrastructure technology. The government's task was to build an environment in which such decisions could be taken. Unfortunately, in the Netherlands, conflicts arose between activities in the grid operation regulation and the support of charging infrastructure in the public area (by grid operators). Whereby grid operation is a public activity by law and charging station operation is seen as a commercial domain. For standardisation, this discussion becomes relevant for interface formats between the EVSE and the power grid. An example is the RCD (safety mandatory), which can be placed in the EVSE or in the circuit. One perspective is to compare EVSE to electricity connections in households, whereby the grid operator is responsible up to and including the meter. In EVSE on public ground, usually a meter is placed as well, which would bring the EVSE under the responsibility of the grid operator. However, that would be commercial domain according to current law in the Netherlands. A different perspective is to see the EVSE separate from the power grid and the responsibility of grid operators ends with the power connection to the EVSE. So, there is definitely an entanglement between different government activities. As a coordination role, the Dutch government established the Formule E-team. This proved to be useful to involve different agencies and to initiate informal and formal standardisation. However, a clear statement is still awaited about the conflicting issue between charging station operation and grid operation. As some stakeholders claim: uncertainty about the different government activities can frustrate the market for charging infrastructure. Therefore, innovation in this development might be restricted.

6.3 Analysis of the Developed Standards

This section describes the types of standards that are used in the Dutch charging infrastructure and what this means for innovation.

The use of formal standards

As reported in the theory, the use of formal standards gains more importance in the development of new products. Firms work together in setting formal standards, because of the accelerating technology life cycle of products, the increasing systemic nature of technology, its growing complexity and rising demand for reliability and quality (König, 2008). However, in the Dutch EV charging infrastructure case, the most important reason was to be connected to international developments. As large firms set standards on an international basis, due to the reasons as mentioned by König, the goal of the Dutch formal standardisation was to keep informed about these developments and be able to raise a voice through a national technical committee in the formal conventions.

To ensure stability through a formal standard, but also to be flexible for international developments, it was chosen to use the least strict form of a formal standard, the NTA. Such a formal standard could be developed quickly, but also be abandoned swiftly, if necessary. For innovation, this can be regarded as beneficial, because indeed both stability and flexibility are regarded as essential for an infrastructure that supports innovation (Hanseth, 1996).

Compatibility standards (interface formats)

This section is about agreements that connect components in the infrastructure. The interface formats discussed here, guarantee *one* infrastructure that works together, which prevents unnecessary investments. A distinction is made for three types of compatibility standards: physical standards, communication standards and standards by convention (Farrel and Saloner, 1987).

Physical

To achieve physical compatibility, one type of socket had to be chosen for the public charging infrastructure in the Netherlands (Type 2). While it does narrow innovativeness for the development of sockets, it greatly improved the interoperability with other charging stations and guaranteed one Dutch infrastructure. Internationally, three technical standards were proposed (see Appendix C: Charging Types), without giving a formal preference to either socket. According to interviewees, the chosen socket was the most suitable technology for the short and long term. The limitation in innovativeness was regarded insignificant in comparison to the perceived advantages.

Communication

Two protocols were prime examples for compatibility through communication. The first was the international developed standard Mode 3, through which the charging station communicates with the electric vehicle. The use of this protocol was formally recommended and adopted by all charging station manufacturers in the Netherlands. This was essential for the compatibility between the products of the different manufacturers.

The second protocol was developed by E-laad: OCPP. This protocol determines the communication between charging station and managing central system. The use of this protocol was never formally advised, but it won as a de facto standard because E-laad enforced the use of this protocol to their suppliers.

The flexibility of these communication protocols is key for innovation. While too much flexibility in these standards brought incompatibility issues through interpretation differences, it did start a discussion about its functionality. This functionality could be improved by manufacturers through incremental innovations. In the end, the expectations of manufacturers was that the best functions will end up in the formal standard as well, even though such processed often take a long time. In short, to improve innovativeness in standards, the standard can better be too flexible than too strict.

Convention

A major necessity to provide compatibility between charging service providers was to agree on the market model in which roaming is possible. To achieve this, the choice was made to let RFID cards be the tool for identification and authentication of charging transactions by EV drivers. The convention was to let customers pay with a form of contract, which makes it possible for service providers to settle costs of transactions on an e.g. monthly basis and then bill their clients after this settlement. This would not be possible if EV drivers could charge anonymously and pay-as-they-charge at charging stations. Then, charging stations had a monopoly for their unique location and service providers had to install multiple charging station at one location. However, the question is if municipalities are willing to make much room in the public area. As interviewees mentioned, this uncertainty would undermine any hope of return on investment and would frustrate the market of charging EVs.

The aim of setting these compatibility standards was to enable the market model as described in the results, which facilitated more room for new companies in the market of charging EVs. This competition is regarded as beneficial for the innovative character of the infrastructure.

Performance standards

The focus to describe standards as performance-orientated can be found in the communication protocol OCPP. This protocol was developed to offer one set of functions a charging station minimally had to be capable of, in order to encourage compatibility. How a charging station manufacturer would realise these functions was not prescribed. In addition, the manufacturers were also allowed to build new or better functions in their product. Such efforts would not be disturbed by the communication standard and could serve as unique selling points. Attributes like this in a standard are supportive for innovation as it stimulates finding new or improved functions by manufacturers.

For a physical compatibility standard like the Type 2 socket, it was not possible to describe it as a performance standard. The design of the socket was determined in a formal standardisation process on international level. Implication for innovation can be made by making a difference between physical interface formats and non-physical standards. While performance standards have a preference for innovation, in the case of physical interface formats for charging infrastructure, the use of design standards is not avoidable.

7. Conclusion

The goal of this research was to describe the standardisation of the Dutch charging infrastructure and its impact on innovation in that area. A distinction was made between the *process* of standardisation and its result or the *types* of standards that were developed. The method I chose was to perform a case study and to hold in-depth interviews with stakeholders involved in the process of building the Dutch charging infrastructure. The main scope of this case study is infrastructure for AC normal charging on (semi-)public ground. For the standardisation process, the aim of this case study was to answer the following research question:

RQ1: What aspects influenced the standardisation process of the Dutch EV charging infrastructure and what implications can be identified for innovation?

The standardisation process of the Dutch EV charging infrastructure took place on two levels. Firstly, there was the informal standardisation process, which was initiated by the Formule E-team. This team was established by the Dutch ministry of economic affairs. The team gathered market players by organising meetings and discussing issues with infrastructure, for example compatibility between charging stations. The solutions and agreements achieved in this process can be called informal, because no formal standard-setting body was involved. When the formal standard-setting body NEN became involved, the second level of standardisation started. Both levels co-existed next to each other. However, initial solutions came from the informal process.

An interesting aspect of this case is that in the Netherlands relatively many SMEs were active in the standardisation process. This is in contrast with the prediction from theory that large organisations in particular participate in standardisation. It might be concluded that the recommendation to engage all stakeholders in standardisation was well executed. The choice of the government to support standardisation within a formal setting and in an informal setting had an important impact. Both enabled an engagement of more stakeholders in the standardisation process of the Dutch charging infrastructure. Especially SMEs used this support to be actively involved, which can be regarded as a healthier way to set standards for innovation in the Dutch charging infrastructure than if only large, incumbent organisations decide on standards. SMEs defended the stakes of the smaller companies involved in the Dutch market for charging EVs.

The Dutch government wished to present itself to be supportive, but not decisive for a national charging infrastructure. Policy was to support all different sort of activities by stakeholders. This was done by financing facilitators for meetings, studies and standard-setting. The main idea was to let the market decide on agreements, as for example compatible charging infrastructure technology. The government’s task was to build an environment in which such decisions could be taken. Unfortunately, the Dutch grid operation regulation and laws accompanied with that had an impact on the activities of stakeholders for charging infrastructure. This asked a more active role from the Dutch government about legal issues for charging infrastructure. Government coordination between supporting activities and activities that restrict stakeholders might be essential, if the charging infrastructure market grows in the future.

Due to the characteristic of the Netherlands as being a small country, the absolute number of organisations that were involved in the standardisation could be kept limited. This small amount of players ensured a relatively high speed in finding agreements. This might be one of the reasons that the Netherlands could achieve a leadership position within Europe in building a nation-wide charging infrastructure. This leadership involved finding agreements for a roaming method between service providers and for one type of socket in charging stations. Standardising on this Type 2 socket involved a strategic action by grid operators, who rejected the solution offered by Amsterdam (which was the Schuko socket). In cooperation with energy suppliers and German car manufacturers, the Type 2 socket was developed and installed as a de facto standard. This could be realised by choosing EVSE manufacturers as suppliers that supported the smart grids idea of grid operators and by promising a nation-wide infrastructure. Eventual, this led to the acceptance of a formal standard in order to provide national compatibility. This compatibility was essential in executing a market model in which multiple companies compete as service providers. For innovation literature, this is a fine example how the long-term vision of important stakeholders was manifested in the choice for technical standards.

The initial idea of starting the formal standardisation process seemed to be broader than creating a national standard for charging infrastructure. Interestingly, the formal standardisation process had a different goal in the beginning than creating standards for a Dutch charging infrastructure. In principle, the Dutch charging infrastructure could have been realised through informal agreements alone. In contrast to the informal process, the formal procedures in cooperation with a standard-setting body demanded much more bureaucracy. This was often experienced as slow and unproductive for SMEs. However, only by being involved in the formal standardisation process, the Dutch stakeholders could follow and influence the international course of charging infrastructures. A strong signal was sent to other European countries by formalising the choice of the Type 2 sockets, in the hope of persuading other nations to follow the Dutch example. Because in the end, electric vehicles are meant to cross national boundaries and European compatibility in charging infrastructure lowers the threshold of adopting EVs.

The reasons of Dutch organisations to create a national counterpart of the European (CEN) and International (IEC) technical committee for EVs might have interesting implications for standardisation literature. The formal standardisation process was used to gain involvement in the otherwise internationally oriented standardisation process of charging infrastructure. This in contrast with only formalising technical agreements between companies. Even more, in the Dutch case, a majority of informal agreements was explicitly chosen not to be formalised. An explanation might be the absence of a dominant car industry in the Netherlands. In addition to this, stakeholders did not wish to create a national lock-in. Information about development in this industry had to be searched across the Dutch border. Only through a national technical committee, the Netherlands could sent a representative to the CEN/IEC counterpart. In the Netherlands, these representatives were professionals in the EV charging infrastructure industry and provided members in the standardisation groups with knowledge about ongoing developments.

Several agreements were made on an informal basis. This process was seen as constructive by SMEs. However, for innovation, access to these informal agreements might be just as important as access to formal standards. New players in the Dutch EV charging market should not be excluded from information about these agreements. The same might be true for an updated stock of standards. Charging station manufacturers should know about the most up-to-date standards that include state-of-the-art technology. This might prove important for their products, in order to stay compatible with the rest of the Dutch charging infrastructure. The integration of R&D with standardisation of charging infrastructure might be essential for an updated stock of standards.

Overall, important aspects of the standardisation process were the long-term view of grid operators and governmental support to engage stakeholders. The standardisation was executed in a formal and informal process. The formal process included the standard-setting body NEN. The informal process involved meetings of stakeholders in order to provide compatibility in the infrastructure and to solve practical problems. Supportive for innovation were the focus on avoidance of technological lock-ins and the focus on enabling competition. Standards were developed to ensure compatibility between different charging stations and EV service providers. This compatibility was seen as necessary to execute a market model which involves a multitude of companies, competing with each other.

For the types of standards developed, the aim of this case study was to answer the following research question:

RQ2: What types of standards were developed for the Dutch EV charging infrastructure and what implications can be identified for innovation?

In the Dutch EV charging infrastructure case, the most important reason to use formal standards was to stay connected to international developments. The goal of the Dutch formal standardisation was to keep informed about these developments and be able to raise a voice through a national technical committee in the formal conventions. These aspects were part of the *process* of standardisation, as explained in the answer to RQ1. Outcome of this process and a certain *type* of standard, was the Dutch Technical Agreement (NTA). It had the stability of a formal standard, because it was developed within a standard-setting body. Nevertheless, since it could be abandoned relatively easy, it did provide flexibility for new developments in technology for charging infrastructure. Standardisation literature might be expanded about such constructions.

In both the formal as the informal standardisation process, the main type of standards that was developed was the compatibility standard. Such standards ensured a nationwide infrastructure that supported technology from different EVSE manufacturers and EV service providers. This compatibility allowed more players in the market. This competition can be seen as supportive for innovation. The use of performance standards in the description of the compatibility standards for the Dutch charging infrastructure was limited to communication protocols. These protocols are the language between components in the charging infrastructure and are used by charging station manufacturers. Most important communication issues are between EV & charging station and between charging station & managing central system. The aim was to not describe the technology that should be used in order to execute the protocol commands.

This gives the standard an innovative character, as manufacturers can compete with their own solutions in carrying out the protocol. For physical compatibility in charging infrastructure, by definition, the design for a standard socket is fixed. This is about the hardware that connects EV and charging station physically. The need to agree on such a standard is great, as true compatibility for the user starts with having the same sockets for charging EVs. This means a lock-in for a certain technology.

Nevertheless, choices had to be made in order to enable a successful charging infrastructure. Failing to make a choice was perceived as more dangerous by stakeholders than making an incorrect choice. This includes also choices for compatibility that were achieved by convention: in the Dutch case it was agreed to use RFID cards as method of identification. This choice demanded strict design specifications, because interpretation differences could endanger the compatibility. It was chosen not to formalise this agreement within a standard-setting body. It was believed by stakeholders that this identification method could be subject to change in the future (identification from the vehicle) and to put it in a norm could hamper this innovation. Thus when changes were expected, stakeholders provided flexibility in standardisation of the Dutch charging infrastructure by maintaining de facto standards.

To wrap things up, as a formal standard, the use of the NTA was a smart move to combine the flexibility and pace of an informal agreement with the stability of a norm. Flexibility in the standards, by describing only performances, was seen as beneficial for innovation in charging infrastructure, but was limited to communication compatibility standards. Stability of the Dutch EV charging infrastructure was created by choosing a fixed design for the socket of charging stations and by creating a roaming model for EV service providers by convention.

8. Discussion

The development of electric vehicles and charging infrastructure takes place in a rapid pace. On an almost weekly basis, new facts and advancements in this area can be witnessed. In January 2012, when the research proposal for this thesis was finalised, the initial idea was to give advice on the standardisation for an upcoming market model for EV. However, during the research, the organisations already took actions that completed agreements on interfaces necessary for the market model, which went live in April 2012. As a consequence, the research shifted towards a more descriptive nature, illustrating the process that got the Netherlands where it is now in relation to charging infrastructure. This is highly relevant as well, because stakeholders were able to turn a theoretical model that supports innovation (the network model) into practice. My first recommendation for future research is to evaluate the Dutch charging infrastructure in a couple of years, when the success of the electric vehicle can be determined and more specific measurements about the innovativeness of charging infrastructure can be assessed.

The main scope of this paper was the (semi-)public AC standard charging infrastructure, because the need to standardise this, was felt most urgently by stakeholders. The adoption of a technical standard about the connector type could be realised quite easily, especially through the harmonisation proposal (see Appendix C: Charging Types), whereby charging cables are not installed to the EVSE. An entirely different case is the situation around fast-charging infrastructure. Hereby, multiple non-compatible standards are under discussion and the result could be an interface format battle. My second recommendation for future research is to investigate this technological trajectory more carefully, perhaps using the theoretical framework proposed by Van de Kaa et al. (2011). This framework describes factors for format dominance and by analysing the factors that are relevant in this case, a cautious prediction of a winner could be made.

Important to notice: the factual information stated in this thesis might already be outdated when you read this, which was also mentioned by several interviewees. As much as possible I tried to update the information during the process, but at some point the thesis had to be finished. Nevertheless, more important than state-of-the-art factual knowledge is the knowledge gained about the process that enabled the standardisation of a whole new market. A market that had to be created without being able to use examples from other nations. This is the real contribution I hope to have made with this thesis.

Glossary

AC charging: The EVSE supplies alternate current to the vehicle's on-board charger, which charges the battery.

ACEA: European Automobile Manufacturers' Association. Members are for example BMW, Daimler, PSA and Volkswagen.

CEE: Certification of Electrotechnical Equipment. Jargon for industrial plugs that can handle (high) voltages.

CHAdeMO: CHArge de MOve. Japanese charging specification for fast DC charging up to 50kW.

Charge Data Record: Clearing and settlement protocol between service providers and charge point operators.

Charging level: Category for charging speed or power level that is provided by charge points.

Charging mode: Type of charging method and installed charging infrastructure.

Charging station operator: Is responsible and in control of EVSE.

Charging type: Describes the physical connection (plug) between vehicle and EVSE.

CIR: Centraal Interoperabiliteitsregister. Central databaseserver that collects and provides RFID card numbers that have a service provider contract.

Cloud: Jargon for a online system/server.

Combo: Jargon for Combined Charging System (CCS), which combines AC and DC charging in one connector/inlet.

DC charging: The EVSE charges the vehicle's battery with direct current right away.

DOET: Dutch Organisation for Electric Transport. Industry association for electric mobility in the Netherlands.

Energy supplier: Responsible of energy (and thus electricity) production.

EVSE: Electric Vehicle Supply Equipment. Technical term for charging station.

GPRS: General Packet Radio Service. Technology that provides wireless internet connection continously.

Grid operator: Is responsible for the transmission of electricity. Maintains and installs the power grid and its connections.

Interface: Point of interaction between systems or components.

Market consultation: Private organisations and government team up to realise a common goal.

Market segment: Part of a market, based on one or more similiar characteristics.

MIFARE: trademark from NXP Semiconductors for contactless smart cards, enabling RFID.

Norm: Formal agreement/standard. Underwent an approval process by other norm commissions on which decisions the agreement might have impacts, or vice versa.

NTA: Dutch Technical Agreement. Formal agreement between organisations about the use of a certain technology.

OCPP: Open Charge Point Protocol. Communication protocol between EVSE and backoffice.

Schuko: Schutzkontakt. Colloquial name for CEE 7/4. Standard outlet in the Netherlands.

Service provider: Enables the charging service for EV owners at (public) charge points.

Standard Contract ID: Identifier used by service providers to link charge transactions to their customers.

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Appendices

Appendix A: Charging Levels

This is the category for describing the speed of charging, or strictly spoken the power level, for conductive AC charging. A higher power level resembles faster charging. It depends on the number of phases (one or three), the voltage and the current that is used. This results in power.

$$P = \sqrt{nPhases} \times \Delta V \times I \times cos\emptyset \; (cos\emptyset = 1)$$

Table 5. Charging Levels (adapted from Van den Bossche, 2010)

	Voltage (V)	Phases	Current (A)	Power (kW)
EU Standard	230	1	16	3.7
EU Semi-fast	230	1	32	7.4
EU Semi-fast	400	3	16	11.1
EU Semi-fast	400	3	32	22.2
EU Fast	400	3	63	43.5

In the Netherlands, EU Standard is used for most public AC charging stations. In theory, higher charging levels are possible, however, that depends on the connection contract with the grid operator (a higher current means higher transportation costs) and if the electric vehicle is able to charge on three-phase. Also, often the internal chargers of EVs are regulated on a fixed power level.

In addition to these AC charging levels, there is the possibility to charge fast by using a DC charger outside the vehicle that can handle a much higher current (up to 400 A).

Appendix B: Charging Modes

Apart from the charging level, it is important to differentiate between the methods and installed infrastructure that can be used to charge EVs: charging modes. The international norm IEC 61851-1 (IEC, 2010) describes 4 modes.

Table 6. Charging Modes (adapted from Van den Bossche, 2010)

	AC/DC	Description
Mode 1	AC	'Dumb' charging. Based on national standardised socket outlets.
Mode 2	AC	Provides extra safety by adding an in-cable control box that recognizes if the EV is correctly connected.
Mode 3	AC	With this mode, direct communication takes place between the car and the charging station.
Mode 4	DC	Used for DC (fast) charging, whereby the charger is outside the vehicle and the cable keeps attached to the charging station permanently.

The advantages of being able to communicate with the vehicle are additional safety and service. Mode 2 (fig. 10) and 3 describe that the cable only delivers electricity once the vehicle is correctly connected, verified through a control pilot conductor. The disadvantage of mode 2 is that the plug is not protected (this is still the 'dumb' plug, see Mode 1). Communication


Figure 10. Mode 2 cable

further adds the service that data exchange functions can take place that makes it possible to use smart charging and billing.

Appendix C: Charging Types

The category 'charging types' describes the physical connection between vehicle and charging station. The international norm IEC 62196-2 (IEC, 2011) describes three types that can be used as plugs and sockets.

Table 7. Charging Types (IEC 62196-2)

	Name	Origin	Distinctive
Type 1	SAE J1772-2009	US and Asia	Based on single phase charging: 5 connect pins
Type 2	VDE-AR-E 2623-2-2	Germany	Offers one layout for 16A single-phase up to 63A three-phase.
Type 3	EV Plug Alliance	France and Italy	Includes shutters, that are required by some European countries by law

At this moment, the vehicles from the US and Japan have a Type 1 socket. However, naturally that does not prevent the charging stations to have a different type of socket, as long the EV driver possesses a cable to connect between the different types (fig. 11).

Figure 11. The three charging types (from left to right: Type 1, Type 2 and Type 3)

Compatibility between these different types can be assured by using sockets at the charging stations instead of fixed cables (fig. 12).

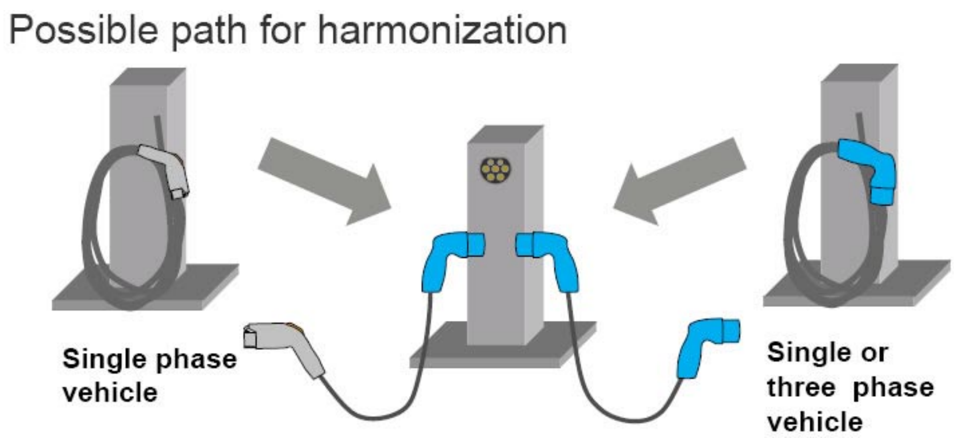

Figure 12. Charging of vehicles that use either Type 1 or Type 2 sockets at the same charging station (figure from Oestreicher et al., 2009)

Appendix D: Charging Market Segments

The following market segmentation can be identified for charging infrastructure, based on the type of property on which charging stations can be installed.

- Private
- Semi-Private
  - Commercial (e.g. parking areas of fast-food restaurants)
  - Non-Commercial (e.g. parking areas of churches)
- Public
  - Public urban areas
  - Public highway rest areas

Appendix E: List of Interviewees

Type Organisation	Organisation	Interviewee	Date
Consultant - Electric Vehicles in NL	ex DOET	Tim Kreukniet	14-mar
Consultant - Standardisation	NEN NEC	Gertjan van den Akker	23-feb
Consultant - Standardisation	Movares/IEC	Teus de Zwart	29-feb
Consultant -Engineer	Movares [Pilot]	Ron Visser	22-feb
Consultant -Facilitator	P2	Joris Jansen	23-mar
Energy Supplier	Eneco	Paul Broos	8-mar
Energy Supplier	HVC	Maarten de Wit	2-apr
Software/Consultancy	Logica/TNO	Michel Bayings	2-may
Government - Competition Authority	NMa	Elozona Ochu	29-mar
Government - Economics	EL&I	Tjaling de Vries	9-mar
Government - Infrastructure	Rijkswaterstaat	Frank ten Wolde	21-mar
Grid Operator/Service Provider	E-laad	Bram van Eijsden	22-mar
Grid Operator	Enexis	Andre Postma	5-mar
Manufacturer	Epyon Power	Wouter Robers	8-mar
Manufacturer	Hateha	Sjaak Hissink	8-mar
Manufacturer	Chargepoint	Robert-Jan Brouwer	13-mar
Manufacturer/ Service Provider	The New Motion	Wouter de Ridder	5-apr

Appendix F: Example Semi-Structured Interview

Below is one of the topic lists that were used during the interviews. This topic list serves as an example for all semi-structured interviews:

The New Motion 10.00 uur

- Vragen naar tijd voor dit interview
- Opnemen? Puur voor eigen analyse en 100% vertrouwelijk
- Introductie over mezelf/opleiding SIM/dit onderzoek
- Interview over de wens van The New Motion voor de toekomst, hoe standaardisatie daar aan bij kan dragen en hoe het krachtenveld van bedrijven daarin een rol speelt.

Algemene onderwerpen

- ✓ The New Motion
- ✓ Wouter de Ridder
- ☐ Functie in het bedrijf
- ☐ Geschiedenis van The New Motion
  - ☐ Aantal werknemers (FTE)
  - ☐ Leeftijd en ontstaansgeschiedenis bedrijf?
  - ☐ Partners/Samenwerkingsverbanden

Hoofdonderwerpen

- ☐ Wat is de relatie van The New Motion met de oplaadinfrastructuur van elektrische auto's?
  - ☐ Wat valt er voor The New Motion te winnen?
- ☐ Wat is de verwachting voor de toekomst van een laadinfrastructuur in Nederland?
  - ☐ Wens van het bedrijf versus verwachte realiteit
  - ☐ Knelpunten in het ontwikkelen van deze realiteit
    - ☐ Hoe kan standaardisatie hierbij een rol spelen?
    - ☐ Wat moet er op het gebied van standaardisatie nog gebeuren om elektrisch rijden innovatief te laten verlopen en wat juist niet?
- ☐ Hoe spelen afspraken, normen en standaarden tegenwoordig een rol?
  - ☐ Formele versus informele standaarden
    - ☐ Rol van NEN NEC 69 als formele partij
    - ☐ Rol van samenwerkingsverbanden als informele partij
      - ☐ Wat voor samenwerkingsverbanden zijn er?
  - ☐ Belemmerende rol versus ondersteunende rol
    - ☐ Patent/licenties?
    - ☐ Ruimte voor innovatie?
  - ☐ Nationale (lokale) normen versus Europese/Internationale afspraken?
    - ☐ Hoe beïnvloed het de lokale bezigheden?
- ☐ The New Motion en het marktmodel
  - ☐ Waar zijn laadpalen van TNM? Publiek/Privaat Alleen maar loloo en snelladers?
  - ☐ Rollen splitsen laaddienstprovider en laadpaalexploitant?
  - ☐ Hoe speelt standaardisatie en innovatie hierbij een rol?
  - ☐ Hoe wordt straks normale publieke punten laden verrekend?